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SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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GRADY TRIPLETT
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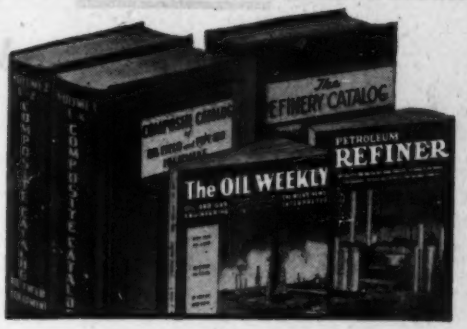

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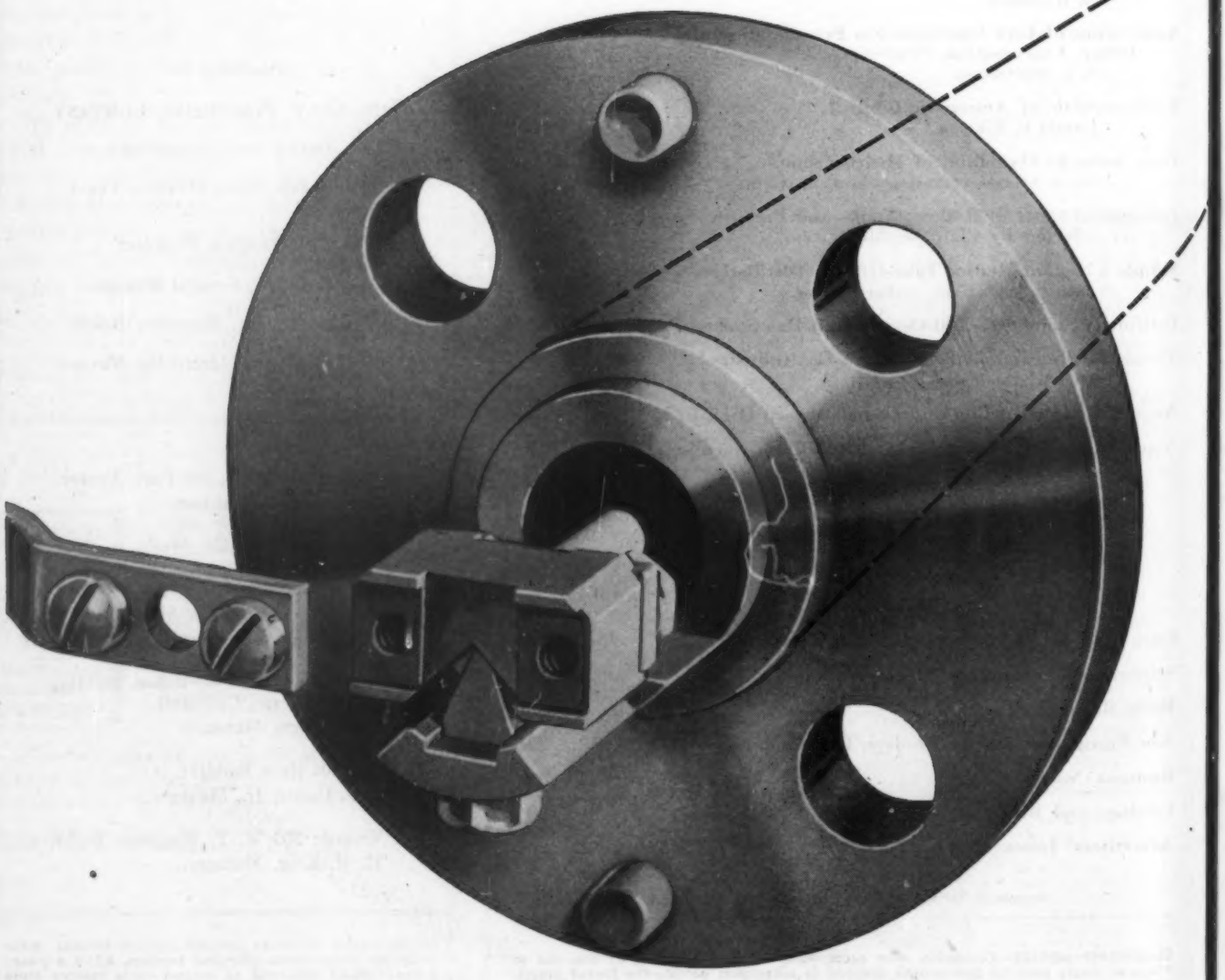

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THE LOOK BOX

SOMEHOW a half-million barrels of fighting-grade aviation gasoline each day seemed enough. The knowledge that deliveries exceeded the charmed half-million figure added confidence to assurance. The figure was reached prior to completion of two aviation-gasoline units on the West Coast in January.

Just Not Enough

All in all it simply added up to doing a big job in a big way.

Still, it is not enough. Two more plants have been authorized and indications are that still other units will be started this year. It will not be surprising if the industry reaches 600,000 barrels of 100-octane aviation gasoline per day by the end of this year.

There is, of course, the need for the super fuel for the super fortress, the product with 100-octane rating for ordinary consumption and the reserve for extraordinary action when occasion demands. Plants that make it will produce less than their rated capacity on 100-octane fuel.

The super fortress is in part responsible for the necessity for adding to plant capacity. A mission bound for Tokyo requires each of these machines to take on the contents of a tank car. Although the war in the Pacific steadily brings the fueling bases closer to the targets, the number of these monster airplanes continues to increase.

The only answer is more gasoline, and that means more plant capacity. Fortunately the experience from building the early units will permit quicker and cheaper construction of new ones. Operating personnel have learned how to exact the most from the new processes.

However disappointing it may be to realize that a half-million barrels is not enough, it is comforting to know that more can be provided, and soon.

ONE of the inconsistent results of mixing mechanics and economics is that the machine, which men oppose in fear of it taking their jobs, always plays a role in giving jobs to more men. Despite this record, men still fear the machine.

Why Fear Machines?

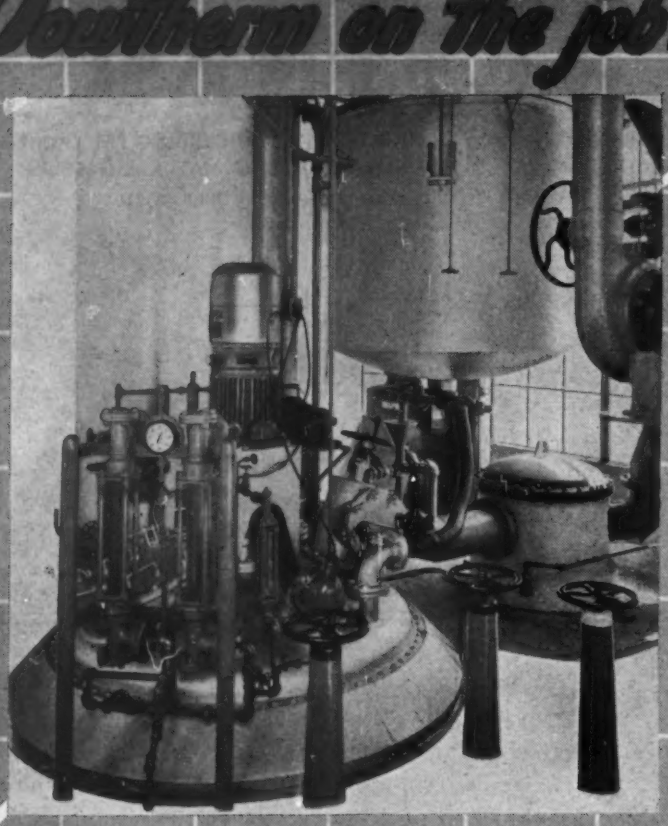
Opposition to the first pipe line from Oil Creek to the Atlantic seaboard was the first instance of this situation in the petroleum industry. The mule driver, the mule owners and the owners of lodging facilities saw in the pipe line nothing but disaster.

But transportation by pumps simply put the teamster into another job. The efficient machine does that always. But men still fear the machine. Whether they will learn to evaluate it in true perspective is doubtful.

The benefits are twofold. The machine brings about lower manufacturing costs with the result that more people can have the finished product. That requires more men in manufacturing despite the presence of the machine.

The other benefit is perhaps more beneficial. It has permitted men and women who make products to enjoy what they make. For proof, recall the pictures of prewar automobile factories. The automo-

Dowtherm on the job!



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biles of the plant personnel covered more acres of parking space than the plants occupied.

It is worth remembering. The next time a machine looms as a threat, give it a mental whirl. The development may be friendly rather than vicious.

Big Job

THE accomplishment of producing chemical rubber at the rate of 1,000,000 tons per year in the United States is significant when measured by consumption of rubber. It was in 1941 that the world set its record of rubber consumption. The total for the United States was 783,000 tons and world consumption was 1,104,000 tons.

Thus, within two years, the alcohol, chemical, petroleum and rubber industries have set in operation the facilities by which they can produce more rubber than peak requirements ever reached. The possible production lacks but little in being sufficient for the highest total of world consumption.

Indications are that full production of these plants will be needed in the first two years following the end of the war, regardless of what comes about in natural rubber circles. Until natural rubber plantations and plants can be restored, chemical rubber must carry the load.

After two years chemical and natural rubbers will come into competition on cost and quality considerations.

Sharp Turn Downward

THERE is little doubt that world-wide consumption of petroleum products immediately after the war will be substantially lower than the total for a corresponding period prior to the war. The reduction in the number of automobiles will dictate this condition.

Thus far in the United States automobiles have not been discarded as promptly as statisticians calculated. When the automobile factories ceased making cars and turned to tanks and guns, men were quick to draw curves to depict what would happen to the total of automobiles in use. Under necessity, however, it has been learned that the automobile had usefulness beyond the calculations of the statistician.

This extreme care and determination are not sufficient to hold the total at its peak. The longer the automobile plants are on war production the faster cars will disappear. When factories do return to normal work they must replace what obsolescence has claimed. Until manufacturing catches up with wear, motor-fuel use will be less than before the war.

This will apply in Europe as well. The world must have a spell for catching up with itself. In that spell consumption of motor fuel and lubricants must find their place.

Double Benefit

IT WOULD profit men to judge the system of free enterprise on the basis of what it has provided for men rather than on the basis of riches it may have brought a few individuals. The demagogue always points to the wealth permissible under the system as a means of inciting other men to detest the system.

But the men asked to detest the system are also benefited by it. In oil a few men have become wealthy. But the system has given to all men the cheapest motor fuel on the face of the globe as well as the greatest quantity of it. It is worth noting that the industry developed under free enterprise is providing the gasoline and lubricants for the armies that fight under collectivism.

There is nothing gained by making sure a few men never become wealthy when the consequent result is that other men have neither fuel nor automobiles for enjoyment.

Just Do Not Laugh

IT MAY be that little more will be heard of the activities of Frank Perry, whose claims of a gasless automobile have drawn attention from Henry J. Kaiser. Claims of that nature come along just often enough to bring a figurative shrug to the big broad shoulders of petroleum.

Perry may have something and he may not. The next dozen may come to attention and then prove valueless.

What the men of the petroleum industry should never assume is that another energy source is impossible. The claims of Perry have been of sufficient standing to warrant attention from a leading industrialist. The fact that Kaiser would welcome a departure in automobile fuel is significant.

This industry should never indulge in complacency. Gasoline, although it is a highly desirable fuel, is not more than 10 percent efficient. It is reasonable for men to seek something more efficient. It is possible that some man will find it.

It may be the steam engine. In several quarters men are working to perfect it for automotive use.

It may be some other energy source. When a man claims a "secret fluid" other men should hesitate before they turn on the "guff haw" of ridicule. Should such a claim have the basis of reality, the effect on refining would be staggering.

"Let us remember that the fruits of research always benefit society much more than they do the discoverer."

HOWARD E. FRITZ, *research director, The B. F. Goodrich Company.*

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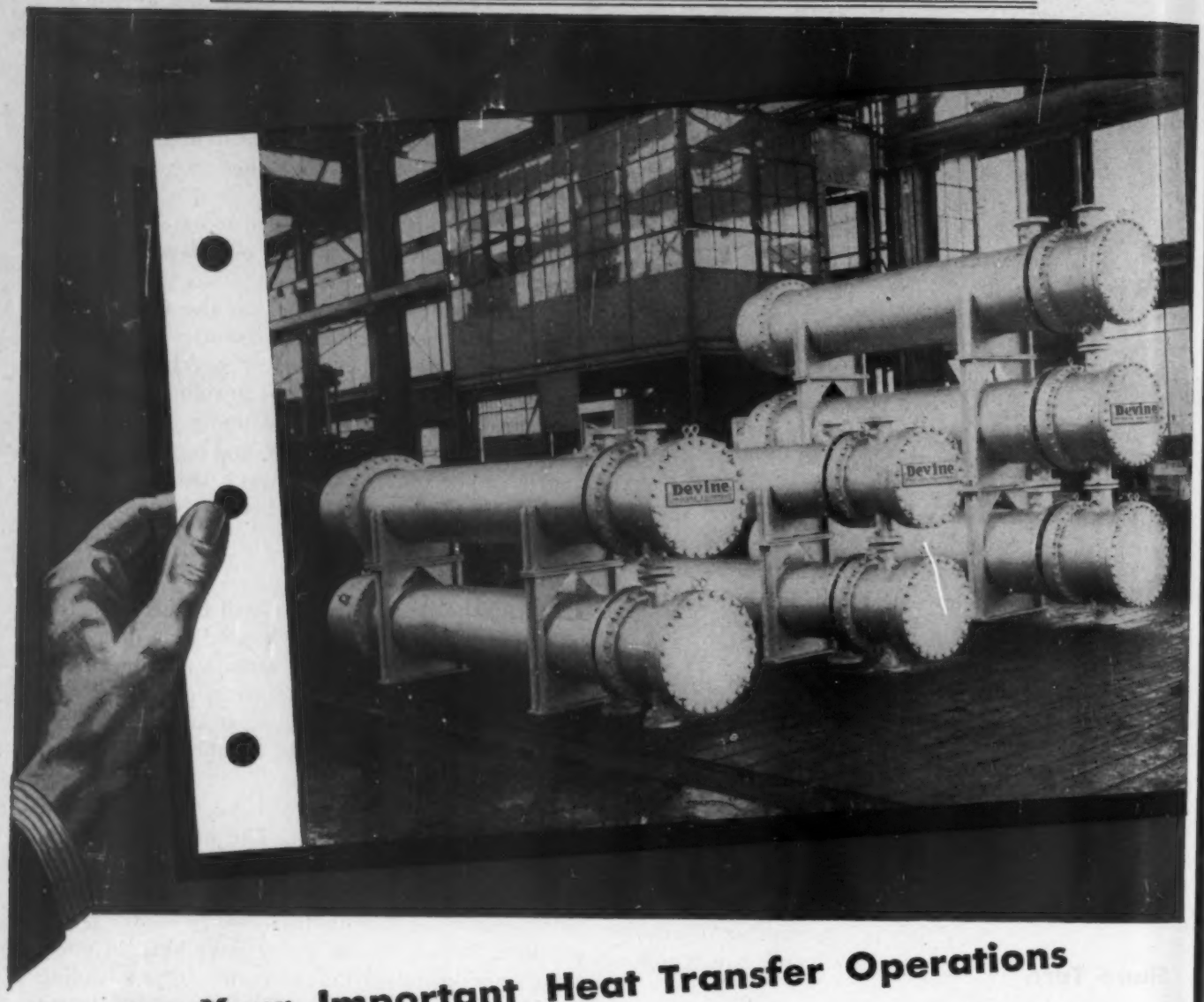

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Sulfuric Acid Extraction in Gasoil Hydrocarbon-Type Analysis

C. C. ALLEN and H. W. DUCKWALL
Anderson-Prichard Research & Development Division, Cyril, Oklahoma

GASOIL hydrocarbon-type analysis is of importance in catalytic-cracking operations for the evaluation of feed stock and particularly for indicating the best disposal of once-through cracked product—for further catalytic cracking, thermal cracking, or for engine fuel. Type analysis is likewise useful in gasoil thermal cracking for selection of feed and indicating possible improvement in cracking efficiency.

Methods of type analysis applicable to gasoils have been developed by Vlugter, Waterman and van Westen[1] and by Deanesly and Carleton.[2]

The method of Vlugter, Waterman and van Westen, termed "ring analysis," involves determination of physical properties before and after hydrogenation and gives composition in percent of aromatic rings, percent of naphthenic rings, and percent of paraffinic side-chains.

Deanesly and Carleton's method, termed the "nomographic method," is based on combustion for hydrogen content and refractometric procedure. Composition is calculated in percent aromatic carbon atoms, percent naphthenic carbon atoms, and percent of alkyl carbon atoms.

Another method of hydrocarbon type analysis has recently been suggested[3] which would also seem applicable to gasoils. This method, termed the "extrapolation method," is based on sulfuric-acid absorption and refractometric determinations. The extrapolation method divides a hydrocarbon mixture into two classes: saturates, comprising naphthenes and paraffines, and unsaturates, comprising olefins and aromatics. Further classification as to type must be accomplished by other determinations, such as bromine number and optical dispersion.

Gasoil analyses by the extrapolation method have not heretofore been presented. This paper reports gasoil data and illustrates the use of the method.

It may be noted that hydrocarbon-type analysis methods applicable to low-boiling products such as gasoline[4] are in general inapplicable to gasoils, owing mainly to the diversified types of aromatics encountered in petroleum distillates boiling over 400° F. Similarly, methods which may be satisfactory for lubricating oils[5] may be inappropriate for gasoils[6] until the relation of aromaticity to directly measurable properties such as aniline point is more thoroughly worked out.

Another feature should be mentioned. The ring analysis and nomographic methods have an advantage over the extrapolation method in that analysis is effected without any separation between groups of hydrocarbons. This advantage has, however, an accompanying disadvantage: by analysis without group separation, the disposal of side-chains (as aromatic-attached or naphthenic-attached) is left indefinite.

A further step in hydrocarbon-structure determination is possible by combining a ring or nomographic analysis with an extrapolation analysis: the former to estimate the percentage of aromatic rings or carbon atoms, and the latter to estimate the percentage of aromatic compounds. Results from combining nomographic and extrapolation analyses are given in this paper.

The Extrapolation Method of Analysis

The principle of type analysis by sulfuric-acid absorption has been discussed previously.[3] A brief review may be desirable, however, in order to point out the difference between the extrapolation method and older methods using sulfuric acid.

The object in applying sulfuric acid absorption to a mixture of hydrocarbons is to remove the aromatics and olefins, thus determining the percentage of aromatics and olefins, and leaving a saturated residue from which analysis can be completed. Sulfuric acid taken in strength or quantity sufficient to dissolve all the aromatics in a mixture may, however, attack saturated hydrocarbons and dissolve them in the acid sludge. For explanatory purposes, the action of sulfuric acid on aromatics can be called "physical solution" and the action on the saturates "chemical decomposition." In such a combination of physical and chemical action it is possible in some cases to vary the proportion of reagent and distinguish the two types of action. This is brought about in the extrapolation method by using several portions of sulfuric acid in excess and plotting the residual hydrocarbon properties against the proportion of sulfuric acid taken. Curves are thereby obtained representing decreased saturated hydrocarbon decomposition with decreased sulfuric acid taken so that an

TABLE 1

Inspection of Products of Extraction of a Catalytically Cracked Gasoil

PROPERTY	Original Oil	Raffinate	Extract
Sample Designation	A	A-R	A-E
Gravity, °API	32.3	37.4	23.1
I. B. P.	330	340	356
5 percent	430	438	398
10 percent	452	464	426
20 percent	474	486	446
30 percent	488	500	463
40 percent	499	512	477
50 percent	512	524	488
60 percent	526	538	500
70 percent	540	552	514
80 percent	560	571	530
90 percent	590	600	564
95 percent	621	632	600
E. P.	646	660	610
Recovery	97	98	98
Residue	3	1.6	1.6
Loss	0	0.4	0.4
Universal Viscosity @ 100° F.	35	38	35
Universal Viscosity @ 122° F.	34	35	33
Carbon Residue, percent	0.150	0.086	....
Sulfur, percent	0.40	0.11	0.43
Pour Point, °F.	10	20	—15

TABLE 2

Analysis of Products of Extraction of a Catalytically Cracked Gasoil

Observations	Original Oil	Raffinate	Extract
Sample Designation	A	A-R	A-E
Volume—Percent of Original	.....	66.0	34.0
Weight—Percent of Original	.....	64.0	36.0
Refractive Index 20/D	1.4904	1.4709	1.5283
Density 20/4	0.8602	0.8341	0.9116
Specific Dispersion, 20° C.	148	124	192
Bromine No.	2.0	1.9	2.3
Aniline Point, °F.	136	167	72
Volume—Percent Saturates (Paraffins Plus Naphthenes)	68.5	86.3	39.9
Refractive Index 20/0 of Saturates	1.4470	1.4466	1.4484
Density 20/4 of Saturates	0.8059	0.8043	0.8076
Aniline Point, °F. of Saturates	192.0	192.5	182.0
Calculations:			
Weight—Percent of Saturates (Olefins Plus Aromatics)	35.8	16.8	64.7
Refractive Index 20/D of Unsaturates	1.5848	1.6239	1.5814
Density 20/4 of Unsaturates	0.9782	1.0218	0.9806
Specific Dispersion of Unsaturates	238	253	243
Estimations:			
Percent Olefins	2.6	2.7	2.3
Molecular Weight	200	213	176
Naphthenic Rings/Mol. of Saturates	0.7	0.7	0.7
Aromatic Ring Type	Polynuclear	Polynuclear	Polynuclear

extrapolation to a fictitious zero sulfuric acid corresponds to zero decomposition.

The procedure of the extrapolation method has been described in the introductory article.[3] No alteration in the original procedure has been made, with the exception that a larger volume of sample, 20 ml., has been used for gasoils, extending the method to mixtures containing large proportions of aromatics.

In the gasoil analyses given below, linear extrapolations were obtained in every case, hence there is no doubt as to the applicability of the method.

Accuracy of the Extrapolation Method

To ascertain the accuracy of the extrapolation method in gasoil analysis, an oil was extracted with a selective solvent (methanol, by counter-current extraction with reflux) until a substantial portion had been removed. The original oil and solvent-free extract and raffinate were then each examined by the extrapolation method. Inspections of the products are given in Table 1 and the analytical results in Table 2.

An explanation as the calculations is necessary. The weight-percents of unsaturates in the samples were calculated from the observed volume-percents extrapolated, employing the assumption of linear volume additivity, that is to say:

$$\text{Weight — \% Unsaturates} = \text{Volume — \% Unsaturates} \times \frac{\text{density of unsaturates}}{\text{density of mixture}}$$

The refractive index and the density of the unsaturates were calculated assuming volume additivity as in the earlier work on this subject.[3] The specific dispersion of the unsaturates was calculated assuming that the specific dispersion was proportional to the weight-percent of unsaturates present and that the specific dispersion of the saturates was 98, following customary usage:

$$\text{Specific Dispersion} = (N_F - N_C)\ 10^4.$$

From the nature of this test, two independent statements can be made as to the composition of the oil; one from the analysis of the oil itself and another from the analyses of the extract and raffinate. The extent to which they agree is indicative of the accuracy of the extrapolation method of analysis:

Properties of Oil A

	From Original	From Raffinate and Extracts	Difference
Saturates:			
Volume—Percent	68.5	70.5	2.0
Refractive Index	1.4470	1.4472	0.0002
Density	0.8059	0.8054	0.0005
Unsaturates:			
Weight—Percent	35.8	34.0	1.8
Refractive Index	1.5848	1.6094	0.0246
Density	0.9782	1.0078	0.0296
Specific Dispersion	238	249	11

These data confirm the degree of accuracy of the extrapolation method as estimated previously[3] from tests with pure substances. In particular, the volume percent of saturates seems to be determinable to

TABLE 3

Inspection of Catalytic Cracking Feed Stock and One-Pass Cracked Stock

PROPERTY	Feed Stock	Cycle Stock
Sample Designation	B	C
Gravity, °API	33.2	30.3
I. B. P.	338	408
5 Percent	454	440
10 Percent	480	450
20 Percent	518	470
30 Percent	546	485
40 Percent	574	500
50 Percent	600	518
60 Percent	626	536
70 Percent	653	552
80 Percent	668	584
90 Percent	740	626
95 Percent	....	666
E. P.	....	680
Recovery	97	97.5
Residue	2.5	2.2
Loss	0.5	0.3
Over at Cracking or 760°	93/760	....
Universal Viscosity @ 100° F.	47	36
Universal Viscosity @ 122° F.	41	33
Carbon Residue, Percent	0.034	0.029
Carbon Residue on Highest Boiling, 10 Percent	0.741	0.269
Sulfur, Percent	0.20	0.27
Pour Point, °F.	10	15

TABLE 4

Analysis of Catalytic Cracking Feed Stock and One-Pass Cracked Stock

OBSERVATIONS	Feed Stock	Cycle Stock
Sample Designation	B	C
Refractive Index 20/D	1.4775	1.4962
Density 20/4	0.8554	0.8708
Specific Dispersion, 20° C.	117	153
Bromine No.	1.9	2.3
Aniline Point, °F.	175	139
Volume—Percent of Saturates (Paraffin + Naphthenes)	78.0	67.5
Refractive Index 20/D of Saturates	1.4562	1.4506
Density 20/4 of Saturates	0.8317	0.8135
Aniline Point, °F. of Saturates	202.0	188.5
Calculations:		
Weight—Percent of Saturates (Olefins Plus Aromatics)	24.1	36.9
Refractive Index 20/D of Unsaturates	1.5530	1.5900
Density 20/4 of Unsaturates	0.9494	0.9898
Specific Dispersion of Unsaturates	171	248
Estimations:		
Percent Olefins	2.8	3.0
Molecular Weight	248	200
Naphthenic Rings/Mol. of Saturates	1.4	0.8
Aromatic Ring Type	Mononuclear	Polynuclear

TABLE 5
Inspection of Thermal Cracking Fresh Feed, Coil Feed, and Recycle Stocks

PROPERTY	Fresh Feed	Coil Feed	Recycle
Sample Designation	D	E	F
Gravity, °API	31.8	24.5	18.7
I. B. P.	456	.....	438
5 Percent	528	484	483
10 Percent	547	504	495
20 Percent	577	534	520
30 Percent	604	554	545
40 Percent	629	574	564
50 Percent	658	596	582
60 Percent	685	625	608
70 Percent	710	666	646
80 Percent	736	714	690
90 Percent	.....	744	748
95 Percent	.....	.....	.....
E. P.	.....	.....	.....
Recovery	90	92	93
Residue	9.9	8	7
Loss	0.1	0	0
Over at Cracking or 760°	88.5/760	91/760	92/760
Universal Viscosity @ 100° F	81	.....	56
Universal Viscosity @ 122° F	61	.....	44.5
Carbon Residue, Percent	0.135	.....	0.338
Carbon Residue on Highest Boiling 10 Percent	2.250	3.975	.....
Sulfur, Percent	0.18	0.30	0.41

TABLE 6
Analysis of Thermal Cracking Fresh Feed, Coil Feed, and Recycle Stocks

OBSERVATIONS	Fresh Feed	Coil Feed	Recycle
Sample Designation	D	E	F
Refractive Index 20/D	1.4812	1.5128	1.5388
Density 20/4	0.8630	0.9034	0.9384
Specific Dispersion, 20° C	110	153	178
Bromine No.	1.4	2.1	3.8
Aniline Point, °F	201	144	108
Volume—Percent of Saturates (Paraffins Plus Naphthenes)	72.0	54.0	44.0
Refractive Index 20/D of Saturates	1.4637	1.4641	1.4721
Density 20/4 of Saturates	0.8495	0.8516	0.8686
Aniline Point, °F. of Saturates	221	202	182.0
Calculations:			
Weight—Percent of Unsaturates (Olefins Plus Aromatics)	29.1	49.1	59.2
Refractive Index 20/D of Unsaturates	1.5261	1.5695	1.5913
Density 20/4 of Unsaturates	0.8978	0.9642	0.9932
Specific Dispersion of Unsaturates	139	210	233
Estimations:			
Percent Olefins	2.4	3.3	5.0
Molecular Weight	285	236	220
Naphthenic Rings/Mol. of Saturates	2.0	1.9	2.0
Aromatic Ring Type	Mononuclear	Mononuclear and Polynuclear	Polynuclear

±2.0 percent, incorrectly printed as ±0.2 percent in the earlier article.

Gasoil Processing

The extrapolation method would appear to be useful for following the course of any process which makes a significant change in hydrocarbon composition. For example the data of Table 2 can be plotted in the form of refractive index or density versus volume-percent of unsaturates and almost linear relationships found. In the case of solvent extraction, the data from plots of this kind may be interpolated for simplifying the construction of ternary diagrams.[7] The values of the density of saturates and unsaturates also serve as a guide in choosing a solvent if possible with a density greater or less than the limiting range so that the extraction process will not be halted at an undesirable mid-point. Conversely, if a particular solvent is selected on other grounds, an extrapolation analysis will indicate the approximate extent to which extraction may be carried out (at ordinary temperatures) before the density of the residual oil becomes equal to that of the solvent.

Cracking Stocks

The alteration in properties of a virgin gasoil by catalytic cracking can be seen from the data of Tables 3 and 4. It is evident that the feed contained aromatics averaging as long-chained benzene derivatives whereas the cracked product contained a high percentage of aromatics averaging as naphthalene derivatives, or possibly other multiple-ring structures. The naphthenic content of the virgin gasoil has also been greatly reduced by the catalytic-cracking process. It cannot be said from the data that the polynuclear aromatics originated by hydrogen-stripping of the naphthenes, but this appears to be a plausible presumption.

It should be mentioned that the data entered under the head of "estimations" in Tables 2, 4 and 6, are not properly a part of extrapolation analysis. The percent of olefins was estimated by conventional procedure[8] from the bromine number[9] and an estimate of the average molecular weight. The latter was estimated[10] from the distillation and gravity of the oils. The naphthenic-ring content was estimated[2] from the density and refractive index of the naphthene-plus-paraffin portion of the oil. Aromatic ring type was decided upon by comparison of the calculated unsaturate properties with those of pure substances[11,12,13].

Tables 5 and 6 show the alteration in virgin gasoil by thermal cracking. As in the case of catalytic cracking, the feed stock contained benzene derivatives and the cycle stock a high percentage of polynuclear aromatics. No naphthene hydrogen-stripping is apparent from the data and the origin of the aromatics is not indicated.

Tables 7 and 8 give the inspections and extrapolation analyses of products of thermal cracking of gasoil. It is notable that although the lighter products

TABLE 7
Inspection of Thermal Cracking Gasoil Products

PROPERTY	Heavy Gas-Oil	Medium Gas-Oil	Light Gas-Oil
Sample Designation	G	H	I
Gravity, °API	24.8	37.2	41.2
I. B. P.	.....	324	284
5 Percent	404	392	324
10 Percent	448	405	345
20 Percent	487	419	370
30 Percent	510	427	380
40 Percent	528	434	388
50 Percent	547	440	397
60 Percent	570	444	404
70 Percent	598	449	412
80 Percent	632	456	421
90 Percent	688	464	434
95 Percent	744	474	448
E. P.	.....	489	466
Recovery	97.0	98	97.4
Residue	2.9	1.6	1.7
Loss	0.1	0.4	0.9
Over at Cracking or 760°	96/760	.....	.....
Universal Viscosity @ 100° F	40	34	31
Universal Viscosity @ 122° F	36	32	30
Carbon Residue, Percent	0.013	0.002	0.002
Carbon Residue on Highest Boiling 10 Percent	0.432	0.042	0.036
Sulfur, Percent	0.38	0.09	0.06

TABLE 8
Analysis of Thermal Cracking Gasoil Products

OBSERVATIONS	Heavy Gas-Oil	Medium Gas-Oil	Light Gas-Oil
Sample Designation	G	H	I
Refractive Index 20/D	1.5152	1.4702	1.4584
Density, 20/4	0.9017	0.8350	0.8155
Specific Dispersion, 20° C	167	124	119
Bromine No.	2.7	21.0	26.8
Aniline Point, °F	111	121	119
Volume—Percent of Saturates (Paraffins Plus Naphthenes)	52.2	67.0	65.9
Refractive Index 20/D of Saturates	1.4606	1.4448	1.4381
Density 20/4 of Saturates	0.8426	0.8101	0.7943
Aniline Point, °F. of Saturates	180	168.5	165
Calculations:			
Weight—Percent of Unsaturates (Olefins Plus Aromatics)	51.2	35.0	35.0
Refractive Index 20/D of Unsaturates	1.5748	1.5218	1.4976
Density 20/4 of Unsaturates	0.9663	0.8855	0.8564
Specific Dispersion of Unsaturates	233	172	158
Estimations:			
Percent Olefins	3.7	21.0	26.7
Molecular Weight	208	170	153
Naphthenic Rings/Mol. of Saturates	1.5	1.1	0.9
Aromatic Ring Type	Polynuclear	Mononuclear	Mononuclear

TABLE 9
Deanesly & Carleton Type Analysis of Gasoils

GAS-OIL	Catalytic	Catalytic Cracking		Thermal Cracking			Thermally Cracked Oils		
	Cycle Stock	Feed Stock	Cycle Stock	Fresh Feed	Coil Feed	Recycle	Heavy	Medium	Light
Sample Designation	A	B	C	D	E	F	G	H	I
C=Carbon, Weight—Percent	87.16	86.28	87.27	85.99	87.27	88.25	87.71	86.48	86.47
H=Hydrogen, Weight—Percent	12.17	13.37	12.23	13.58	11.96	10.67	11.29	13.32	13.47
y=100 H/(C+H)	12.26	13.40	12.29	13.64	12.05	10.79	11.41	13.35	13.47
r=Specific Refraction	0.3363	0.3306	0.3356	0.3299	0.3326	0.3337	0.3345	0.3343	0.3349
S=Specific Dispersion	148	117	153	110	153	178	167	124	119
B=Bromine No.	2.0	1.9	2.3	1.4	2.1	3.8	2.7	21.0	26.8
k=Dispersivity Factor	1.93	1.93	2.04	1.84	2.08	2.04	2.03	1.88	1.76
h=Weight—Percent Unsaturation	2.572	0.972	2.339	0.722	2.204	3.380	2.975	1.434	1.482
h_o=Olefinic Unsaturation	0.025	0.024	0.029	0.018	0.027	0 048	0.034	0.265	0.338
h_a=Aromatic Unsaturation	2.547	0.948	2.310	0.704	2.177	3.332	2.941	1.169	1 144
A=Percent of Aromatic C Atoms	34.6	13.0	31.4	9.7	29.5	44.5	39.6	16.1	15 8
Weight—Percent Unsaturates by Extrapolation Analysis	35.8	24.1	36.9	29.1	52.1	59.2	54.8	36.0	36.8
Estimated Percent Olefins	2.6	2.8	3.0	2.4	3.3	5.0	3.7	21.0	26.8

had appreciable proportions boiling above 400°F., there is no evidence of polynuclear aromatics in these fractions.

Comparison of Nomographic and Extrapolation Analysis

The gasoils studied have been analyzed for aromaticity by the method of Deanesly and Carleton[2]. The results appear in Table 9 along with unsaturates determinations by the extrapolation method.

The two methods of analysis complement each other in some cases. For example virgin oil D analyzed as 29.1 percent unsaturates and 2.4 percent olefins, whereas its aromaticity was only 9.7 percent, clearly indicating a mixed type containing approximately twice as many paraffinic or naphthenic carbon atoms as aromatic, per aromatic molecule.

A similar comparison in the case of the catalytically crack oils—samples A and C discloses the interesting fact that the aromatics in these products are practically devoid of side-chains, thus differing in this particular from thermally cracked products, samples F and G.

The two methods taken together also indicate in the case of light cracked oil I that a considerable portion of the olefinic content is contained in aromatic compounds.

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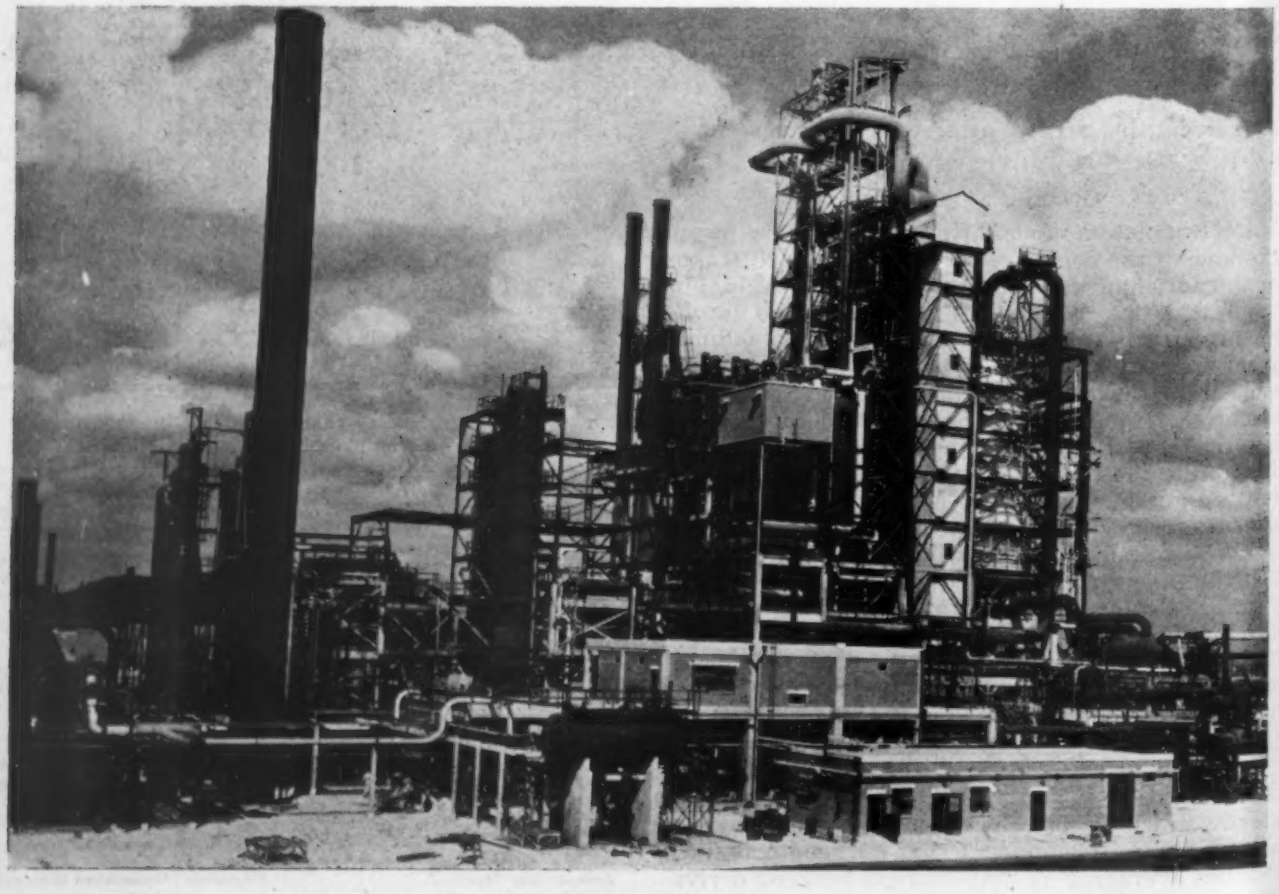

Fluid Catalytic Cracking Unit

Design and Operation of

Hot-Catalyst Elevators

In Thermofor Catalytic Cracking Units

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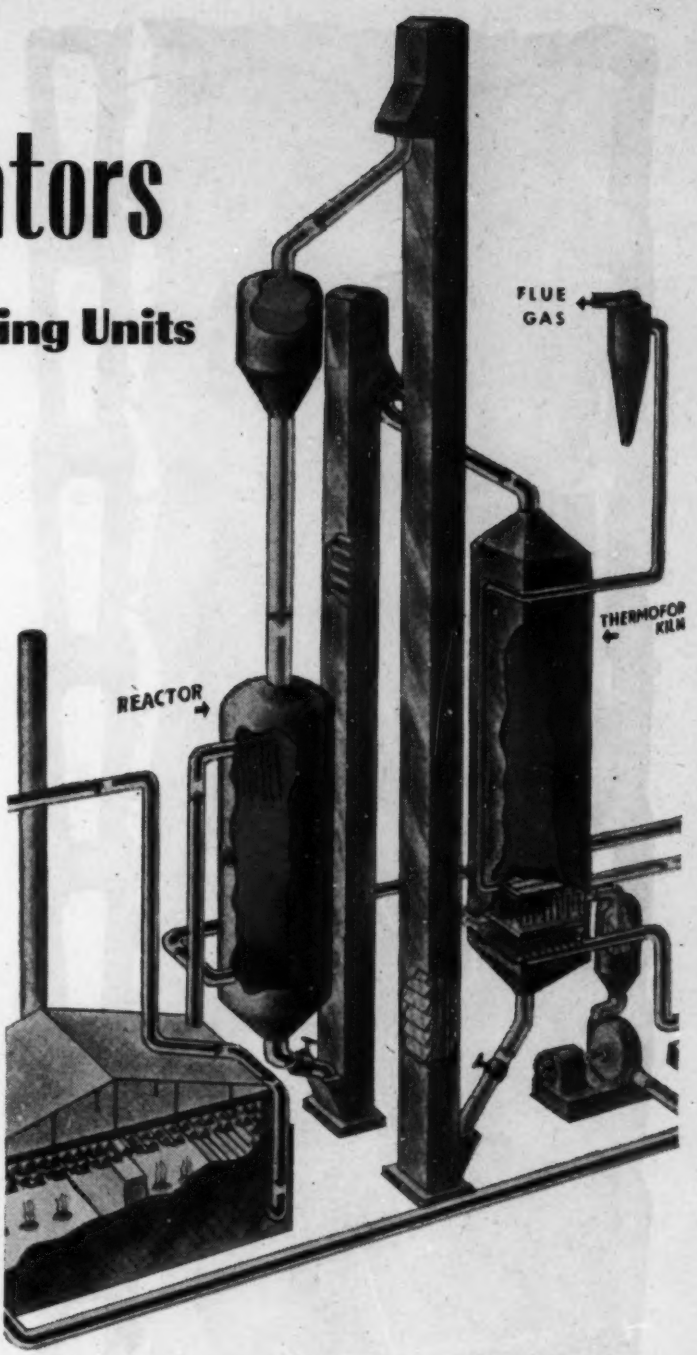
R. R. COLLINS
Vice President, The Lummus Company



THE practice of Thermofor Catalytic Cracking, the general arrangement of units, and discussion of the process problems involved has been ably handled by other writers. This article looks more closely at the mechanical aspects of the problem as presented in the hot-catalyst elevators.

A pair of bucket elevators is required to maintain continuous and uniform flow of the hot catalyst in closed circuit through the reactor and thermofor kiln. Their problem is a major one and unique in several respects. Their approximately 200-foot centers far exceed the heights of bucket elevators in other industries. The high operating temperatures require careful selection of appropriate materials. Continuous operation periods of several months between shut-downs and the absence of any "spare," require extraordinary durability in all details. The elevator casing, supported within its own tower structure has to be reasonably gas tight while yet retaining all necessary provisions for expansion. An inert atmosphere of hot flue gas is maintained within the elevator casing.

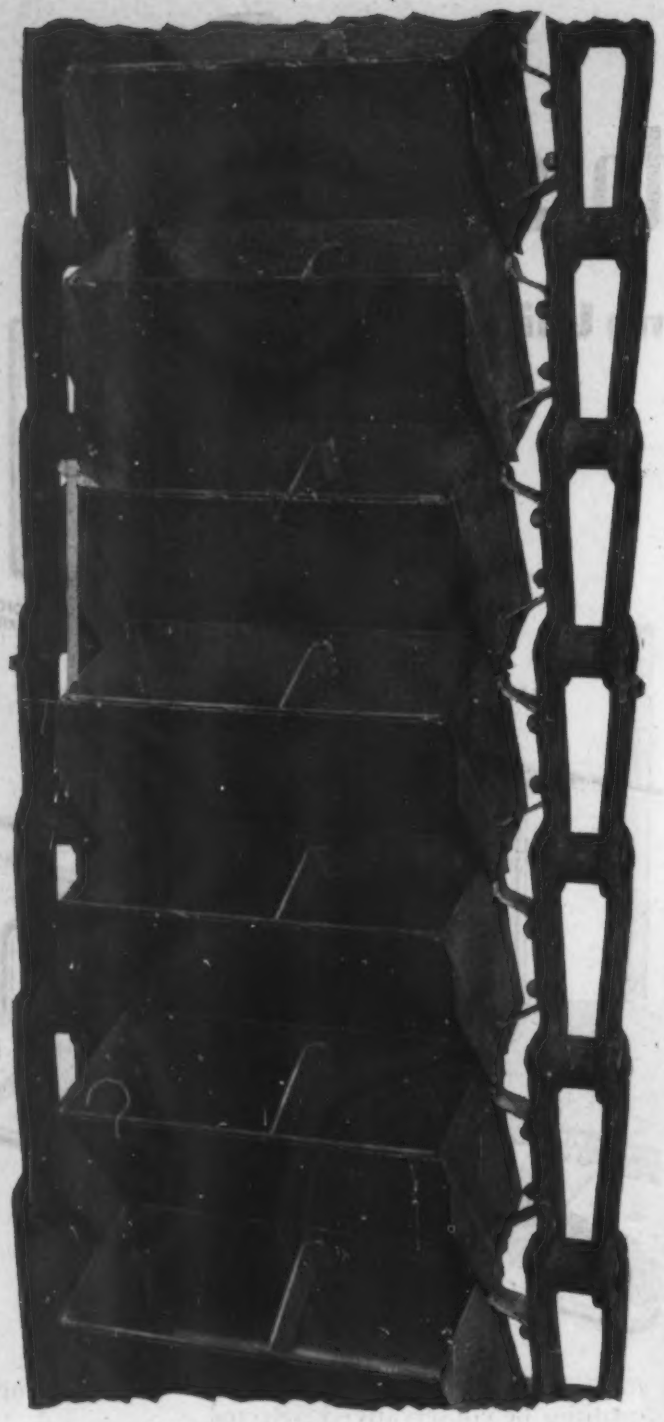
The catalyst weighs between 40 and 50 pounds per cubic foot and must be handled at the approximate rate of 100 tons per hour for 10,000-barrel units, and 150 tons per hour for 15,000-barrel units. To avoid unnecessary damage and degradation of catalyst an elevator of "continuous bucket" design running at slow speed is preferred. An elevator consisting of two strands of 12-inch pitch chain with a continuous line of 9-inch projection buckets, supported between the chains, was therefore selected. The buckets are principally of 10-gauge special specification steel to resist heat, and proportioned so as to reduce discharge spillage to a minimum. The buckets are loosely supported from the elevator chains to permit misalignment without engendering reversal of bending stress in bucket ends and attachments in operation.

Chain Design

The chain posed several questions in design. The height of the elevators dictated a need for all possible economy in chain weight. Employment of two strands of chain dictated selection of materials which would wear uniformly and equally in all joints. The high temperatures in operation compelled selection of suitable alloys; and reliable performance continuously through long periods without opportunity for inspection compelled that all of the foregoing qualities be conservatively selected.

Very little appears to be known of the wear resistance of metals at high temperatures, especially when high working pressures are employed on the surfaces in contact. Lack of time precluded any exhaustive study. A short series of tests were made with many combinations of metals and indicated that suitable wear resistance could be obtained only if other structural qualities were disregarded in one of the two joint members. In other words these tests led to the conclusion that a hard bushing must be used and, because of its brittleness, supported in a steel knuckle. Because of the high working temperatures any such bushing must have a coefficient of expansion closely similar to the steel knuckle supporting it so as to always retain a suitable fit.

High strength with minimum weight combined with the need for mass production of a reliable character recommended the use of rolled-steel sections,



TCC elevator buckets and side chains

rather than castings, for the chain side bars and knuckles, and a technique for welding these into an integral construction was perfected. Despite the size of the knuckle required to suitably support and embrace a bushing this welded construction shows a chain strength through the welded knuckle comparable with the strength of the net section through the pin hole. Chain proportions were selected to show a factor of safety, ultimate to working strength, of about 10 to 1 under operating conditions and after reasonable wear had occurred. Unit pressures in bearing surfaces were held within the conventional values for elevator chains.

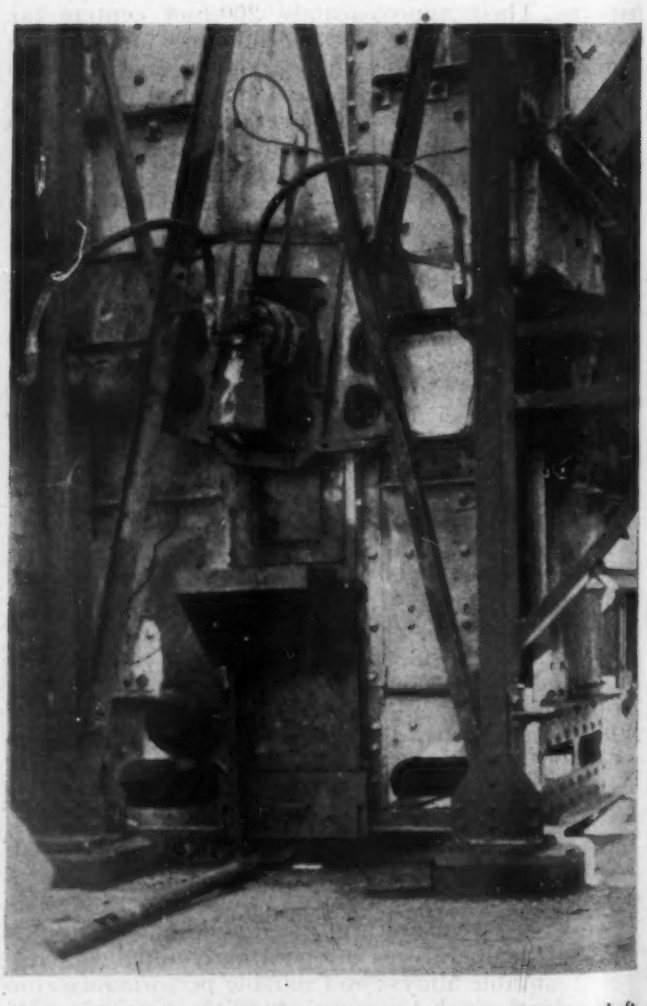
Special Chrome Moly alloy steels are used with varying alloy and carbon and heat-treating specifications to suit the component parts of the chain. The bushing is a high-nickel-chrome alloy iron chill-cast, heat-treated and ground. The ultimate strength of the chain is 200,000 pounds for a designed working load of 15,000 to 18,000 pounds, and a weight per foot of chain of 25½ to 28 pounds.

Extraordinary care is taken in control of special heat treatments of all parts and in shop practice, to produce a chain of unusual uniformity and pitch accuracy.

Sprocket Wear

It was recognized that in elevators of this height the wear on sprocket teeth would also pose a problem. The decision was reached to employ separate, renewable teeth and to coat the wearing surfaces of these teeth with one of the hard-surfacing alloys. Because of the working temperatures, this alloy should have a coefficient of expansion not too greatly dissimilar to the steel tooth body and therefore choice was limited to the ferrous base series of alloys. The first teeth made proved disappointing in service and resulted in a revised construction which employed a high percentage of molybdenum to retain hardness at elevated temperatures and an increase in, and better control of, the finished thickness of hard-surface alloy.

To obtain desired control of alloy thickness the teeth are machined before the alloy is applied and then carefully ground to an accurate profile. Suitable provision also is made to insure that accurate regis-



Bottom of TCC elevator, showing take-up mechanism of bottom shaft

ter is maintained between the teeth on pairs of head sprockets.

The design of head shafts and sprockets required first a decision as to the best way of coping with the heat involved. This heat is practically all produced within the elevator and fed outwards through the shaft, and the heat of friction of the bearings proper is small in comparison. For this reason it was decided to remove excess heat by cooling the shaft directly rather than by cooling through the bearings or lubricant. This method of cooling produces a temperature differential, and therefore thermal stress, between the hub and the rim of the sprocket. These stresses were therefore analyzed and dealt with by constructing the sprocket wheels as a composite construction consisting of concentric rings shrunk together to produce neutral stresses of opposite character and amount, to those stresses produced by temperature differential. The wheels, similarly, are shrunk onto the shaft. The shaft and sprockets are insulated to reduce the extent of these thermal stresses.

Shaft Temperature

With a 900°F. operating temperature within the elevator, design calculations indicated a maximum temperature in the shaft, at the point of maximum stress, of about 600°F.; and shafts were first made of SAE 1045 steel. Trouble was experienced in the operation of these shafts at two installations. Further study evidenced that this steel may show some brittleness (loss of R. A.) at these intermediate temperatures and indicated possible improvement of some details of shop practice. The shaft design was therefore changed to employ A-4140 (chrome moly) steel an to apply all latest know practice in stress relieving grooves where the sprocket wheels are shrunk on.

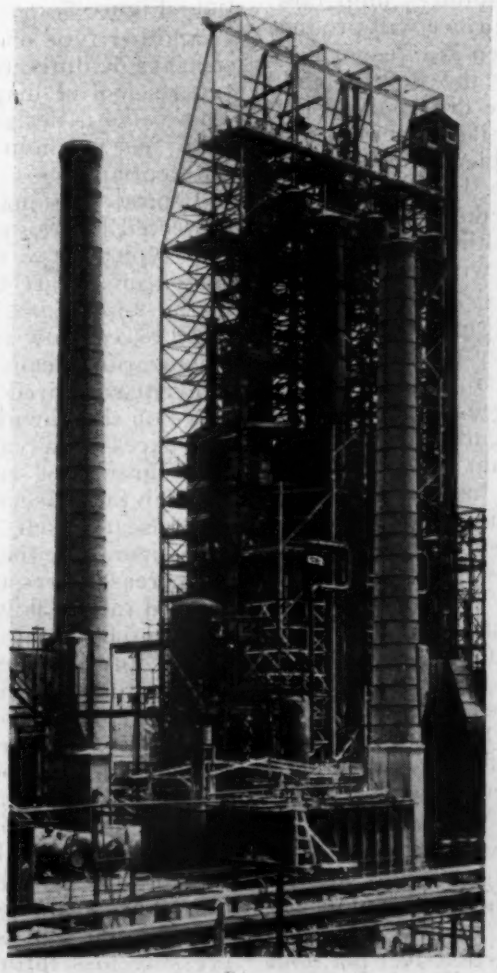
The head shaft bearings are unconventional an have proven strikingly successful. Despite the low speed (20 to 25 feet per minute) an oil lubricant is used and applied in a positively fed circulatory system. The bearing itself is self-aligning, consisting of high-lead-bronze bushings in a ball-and-socket bearing, contained in a cast-iron enclosure, with baffle rings and removable felt retainers. Provision is made for direct inspection of the shaft while in operation and for renewal of bronze bushings without removal of the head shaft or elevator head.

The water cooling system is novel and simple. Through bronze fittings held stationary in each end of the shaft, water is introduced to the inner end of the cooled shaft. It develops a favorable rate of heat exchange by returning through a spiral labyrinth so arranged as to convey any scale or sediment with the water to a discharge port in the bronze fitting. Water consumption is small and need amount to no more than 3 gallons per minute per bearing.

Since the elevator casing is gas tight and should hold against a small positive pressure of several inches of water, a packing gland completes the closure around the shaft. This gland can be conveniently repacked, or tightened when "on stream," and can maintain alignment and concentricity despite expansion and possible warping of casing. As corrosive conditions are present in some elevators these glands are made of silicon bronze and the head shafts are equipped with renewable stainless (25-20) sleeves in this area. This gland is equipped with a gas manifold for purging with conditioned flue gas.

The elevator chains expand considerably (up to about 16 inches) in operation and the foot shaft and related parts are arranged to compensate accordingly. A total of 30 to 33 feet of vertical travel is provided for thermal expansion and chain wear. The foot shaft is tubular, water-cooled like the head shaft and supported in bronze-bushed positive-feed oil-lubricated bearings. These foot bearings are supported in a pivotally mounted gravity-compensated takeup frame equipped with an indicator to show its position. The takeup detail maintains gas-tight provision by passing the foot shaft through a conventional packing gland carried in a ground seal plate which closes the takeup slot by spring pressure against a packed frame on each side of the elevator casing. Provision is made for final alignment and day-to-day adjustment of these packed joints.

The elevator casing consists of panel elements supported within a structural tower which is independent of the main T. C. C. structure but stayed by it against wind. The panel elements are free to slide at their supports so that expansion is integrally provided for. These panels are insulated on their inside face with a suitable insulating block.



Elevator guides are freely supported, within the insulation, from the casing panels and arranged for renewal when necessary. They are made of special specification steel supported by alloy-steel bolts to withstand operating temperatures.

Elevator drives are American standard roller chains in oil-tight enclosures to combination speed reducers and Class D explosion-proof motors.

The elevator is protected from reverse rotation in the case of a power failure, by fully enclosed differential band brakes.

All in all the design of these elevators has involved many new problems and produced some novel solutions. There remain some minor problems which are still being studied and improved. Today, however, it can be said that these elevators have proven themselves adequate for their work and reliable in performance.

Development and Use of Excess-Flow Valves in Liquefied Petroleum Gas Industry

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Chemical Products Department, Phillips Petroleum Company

THE excess-flow check valve, although one of the most important, is the least understood safety device in the liquefied petroleum gas industry. The reasons for this are that each excess-flow valve must be specifically designed and used for a particular application and each valve installation offers its own particular problems. Excess-flow valves of many types are available for a wide variety of uses. Their selection and proper use requires a thorough knowledge of their operation and limitations.

THE excess-flow valve, although widely used, is a safety device not well understood and consequently it is often misused and abused.

An excess-flow valve is intended to serve only one, but one very important purpose. This purpose is to prevent hazards resulting from inadvertent escapage of liquefied petroleum gas by automatically shutting off the flow of liquid or gas to the atmosphere when a line break or other mishap occurs. All of the commercially available types of excess-flow valves utilize the principle of pressure differential across the valve mechanism to produce closeure or shut off. Pressure differential across an orifice or between the inlet and outlet of a pipe or pipe line induces fluid flow. Conversely, fluid flow through an orifice will produce a pressure differential. Closure then is effected by a pressure differential produced by the flow of fluid through the valve. Since a definite differential pressure is required to close the valve it is essential that this pressure differential be available to close a valve for all conditions of tank pressure. It is also important that in normal operating circumstances a pressure differential sufficient to close the valve will not be reached, as this interference with normal flow would be very bothersome.

Excess-flow valves were in early use by the compressed-gas manufacturing industry to protect eduction lines on containers used for storage and transportation purposes. These early excess-flow valves of the weight-loaded ball type (Figure 1) were first employed in the liquefied petroleum gas industry to protect liquid and vapor eduction lines in tank cars. Later they were used on some liquefied petroleum gas storage tanks. These were superseded by the weight-loaded slug type which is now used in all liquefied petroleum gas tank cars (Figure 2). These weight-loaded excess-flow valves had certain installation limitations since such valves must be located in a vertical position with upward flow in order for them to function. In many instances it is desirable or even necessary for the flow to be horizontal or even downward. To provide an excess-flow valve suitable for such purposes the spring-loaded ball or slug type was developed (Figures 3, 4 and 5).

Excess-flow valves are now available for either vapor or liquid duty from the large volume spring-loaded type (9000 gallons per hour at 2 pounds per square inch differential—Figure 6) to the small weight-loaded "flapper" type (175 cubic feet per hour propane vapor at 3 pounds per square inch differential—Figure 7).

Another type of excess-flow valve used for certain special low-differential vapor-flow applications is the super-sensitive diaphragm type shown on Figure 8. This valve is designed to close at approximately 100 cubic feet per hour propane vapor at 1.5 inches H_2O differential.

Typical sectional views of excess-flow valves in protected locations are shown in Figures 10 and 11.

A typical flow curve for an excess-flow valve is shown on Figure 12. This is for the Figure 4 valve in the 2-inch size.

All excess-flow valves are designed with a pressure equalization means to provide a method of unseating in event undesired closure occurs. Closure of the line valve on the downstream side of a "closed" or "shut-off" excess-flow valve will permit pressure equalization through a very small bleed hole or channel through the valve, thus allowing the excess-flow valve to "unseat" itself.

In operation the closure or shut-off is caused by an increased pressure differential produced by an increased rate of flow through the valve. This pressure differential acting across the valve overcomes the spring force. In a well designed valve practically all of the pressure differential across the valve is at the annular constriction between the valve disc and the main body. In other words, pressure drop other than that which will be utilized in effecting closure is avoided as much as possible. This is an extremely important point to be kept in mind not only in the design of the valve but also in the installation thereof. The length of piping and number of fittings to and from an excess-flow valve should be kept to a minimum and should be of ample size so that pressure loss through the pipe and fittings will not

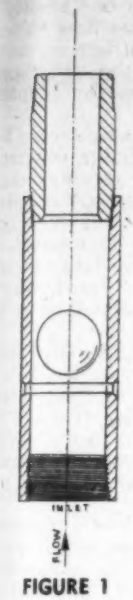


FIGURE 1

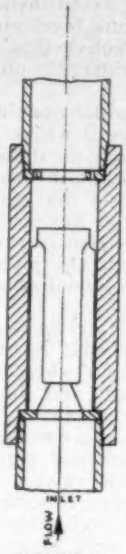


FIGURE 2

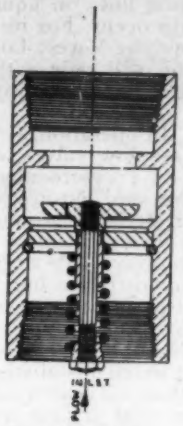


FIGURE 4

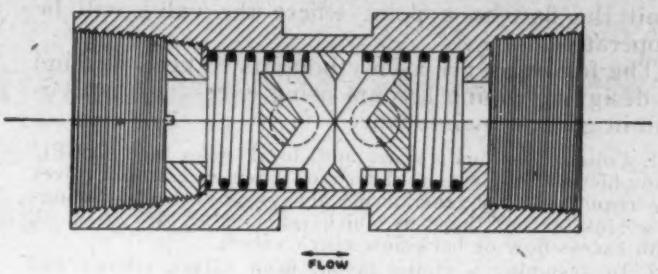


FIGURE 9

FIGURE 5

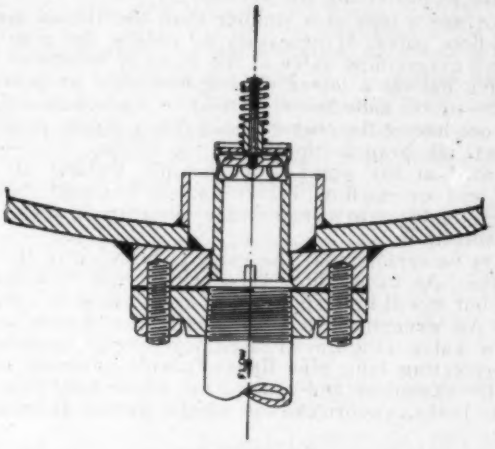


FIGURE 10

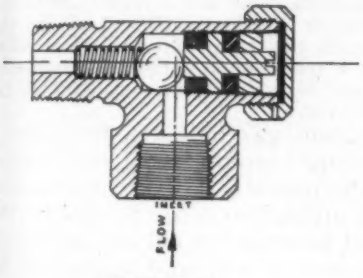


FIGURE 3

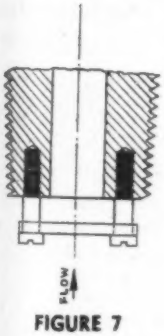


FIGURE 7

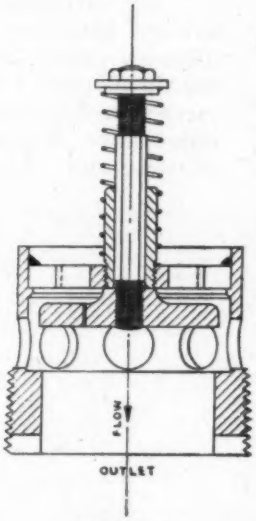


FIGURE 6

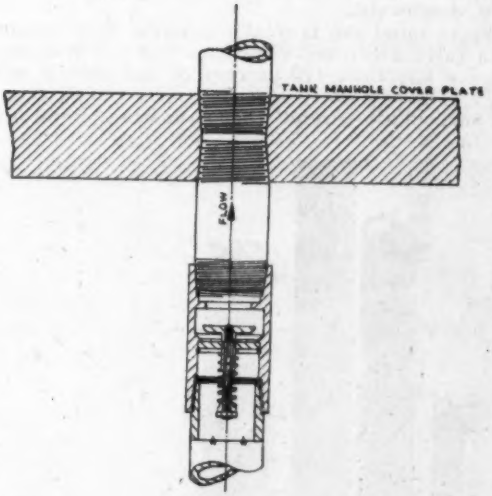


FIGURE 11

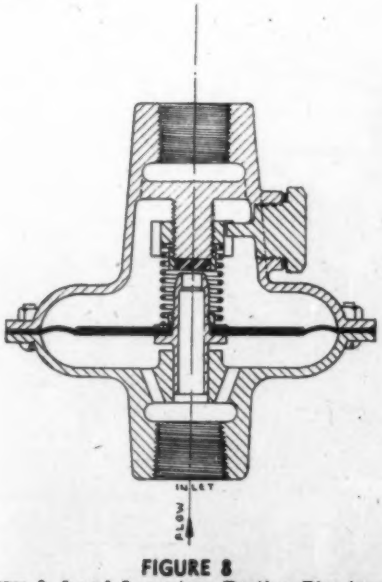
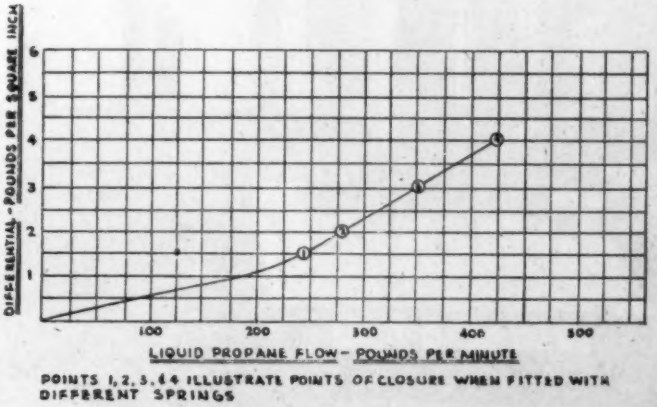


FIGURE 8

Note: Figures 3, 5 and 7 courtesy Bastian Blessing Company.
Figures 8 and 9 patented by Phillips Petroleum Company.



2" - FA-1519 EXCESS FLOW VALVE

FIGURE 12

limit the flow to a point where the valve will be inoperative.

The following are a few thoughts to keep in mind in designing piping layouts using excess flow valves and in general maintenance:

1. Consult national, state and local rules and NBFU Pamphlet 58 Standards to determine when excess-flow valves are required. As a general rule always protect all openings in a tank, except those to which relief valves are attached, with excess-flow or back-flow check valves.

2. In designing a piping layout keep valves, elbows and long lengths of pipe to a minimum as these cause pressure drop and limit the effectiveness of an excess-flow valve at low pressure in protecting the system.

3. Do not use a pipe size smaller than the thread size of the excess-flow valve. If necessary to reduce the pipe size, use a second excess-flow valve at the point of reduction (this second valve having a lesser closing flow rate proportional to the *square of the diametric reduction*) or replace the original valve with one having the *proportionally lower closing flow rate.*

4. Protect all branch lines with individual excess-flow valves located at the point of branching. Protect all pipe lines, line and excess-flow valves against external damage. If the line is subject to considerable vibration always use a flexible connection.

5. Always be certain that the valve is installed in the correct direction. An excess-flow valve will permit flow in both directions but it will be responsive to excess flow in only one direction. An exception to this rule is the double acting excess-flow valve (Figure 9) used for special applications such as protecting long pipe lines. Provide adequate means of caring for expansion and contraction where long pipe lines connect to tanks, vaporizers, or where rigidly fastened to buildings.

6. Note manufacturer's flow specifications as to the physical mounting of the valve. A valve mounted vertically upward will not have the same closing flow as a valve mounted vertically downward.

7. Keep in mind the normal maximum flow requirements. Choose a valve which will close at a flow not in excess of 150 percent nor less than 110 percent of the normal maximum flow.

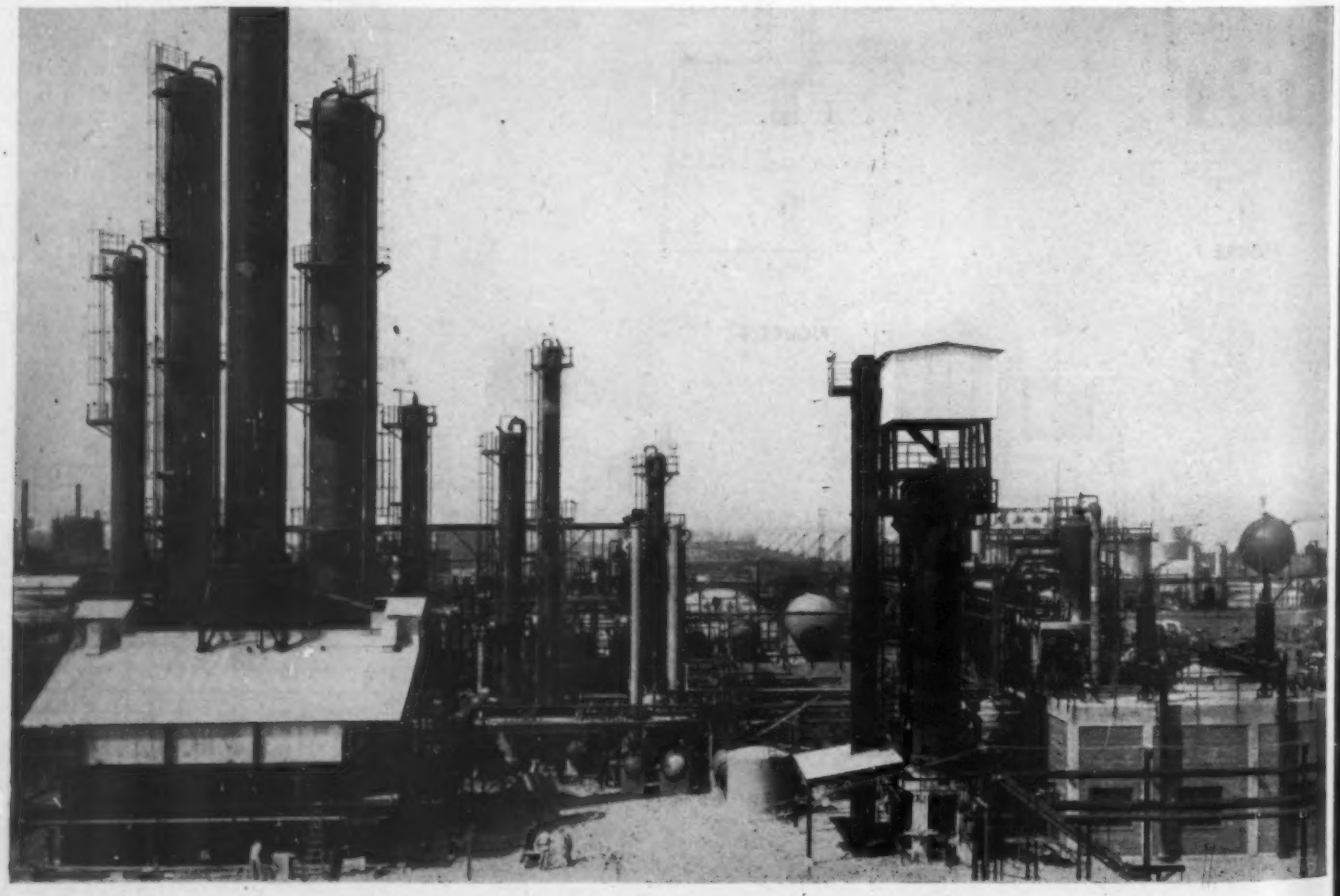
8. Be particularly careful when preparing piping layouts of suction lines on liquid service where cavitation or "gassing" might occur. For instance avoid installing excess-flow valves above the lowest tank liquid level on a suction line as cavitation will reduce the effective flow through the valve and will cause it to close considerably under the designed capacity of the valve.

9. In operation, avoid sudden openings of lines protected by excess-flow valves, especially where an appreciable differential in pressure might exist as these sudden openings may cause slug closure and result in inconvenience to the operator. It is to be understood that an excess-flow valve does not furnish positive shut off but, as previously mentioned, is purposely made to leak so that in case of inadvertent closure a down-stream line valve in the piping can be closed, which will permit the pressure to equalize and the excess-flow valve to reopen.

10. Wherever possible test the equipment not only after the initial installation but also on regular occasions. Select a time of year or condition when the tank or piping pressure is at or near its lowest, and simulate a line breakage by opennig a valve. Take every precaution commensurate with good safety practice as a large liquid line can release an appreciable volume of liquefied petroleum gas prior to the closure of the excess flow valve.

11. Wherever possible and especially on mobile equipment, excess-flow valves should preferably be of a type which when installed are within the shell or manhole of the tank, thus being protected against damage from blows or shearing stresses at the point where the pipe line connects with the tank. A valve such as shown in Figure 6 is ideal for this purpose. For example, with this type of excess-flow valve a bottom outlet line on a truck tank could be completely sheared off without in any way damaging or affecting the action of the excess flow valve.

The liquefied petroleum gas industry has been a leader in developing and employing safety devices of many varieties in the manufacture, transportation, storage, handling and utilization of its products. The industry cannot afford to relax its efforts or neglect the development and use of new and improved devices. Among these the excess-flow valve is high in importance. A planned inspection and regular testing of these and other safety appurtenances is essential.



Isomerization and Alkylation

Physical and Chemical Properties Of Isobutylene

ISOBUTYLENE was discovered and identified by Faraday[1] in 1825 when he subjected animal fats to dry distillation. In 1857 Wurtz[2] prepared this hydrocarbon by the decomposition of fusel oils, by-product of the ethyl alcohol industry. Butlerow[3] prepared isobutylene in 1868 by the dehydration if tertiary butyl alcohol with dilute sulphuric acid. Caventou[4] proved the presence of isobutylene in manufactured gas in 1868. In 1873 Prunier[5] prepared isobutylene by the cracking of a petroleum distillate called ligroin of a boiling point range 60° C. to 90° C. Butlerow[6] studied the effect of varying concentrations of sulphuric acid and water on isobutylene. Fifty percent sulphuric acid converted isobutylene into di-isobutylene, boiling point 216.5° F. (102.5° C.) while 85 percent sulphuric acid converted isobutylene into tri-isobutylene, boiling point 351.5° F. to 352.3° F. (177.5° C. to 178.5° C.). In 1887 Scheschukow[7] studied the reaction of isobutylene with dilute sulphuric acid and obtained ultimately tertiary butyl alcohol. In addition he investigated the action of isobutylene with chlorine and hypochlorous acid.

Within the past 50 years a very large amount of research work has been done and the results have been published regarding the manifold reactions of isobutylene. Of special interest at this time are the following: (a) the addition of isobutane to isobutylene to produce the high-octane gasolines; (b) the self-polymeric change of isobutylene; and (c) the polymerization of isobutylene and butadiene to produce the so-called butyl rubbers.

Vapor Pressures and Specific Gravities

TEMPERATURE		VAPOR PRESSURES			Specific Gravity Liquid	Pounds Per U.S. Gallon	Pounds Per Cu. Ft.
		MM.	Lbs./Sq. In.				
°F.	°C.	Hg.	Abs.	Gage			
−110	−78.9	13	0.25	.....	.....	.....	....
−100	−73.3	20	0.38	.....	.....	.....	.....
− 90	−67.8	29	0.57	.....	.....	.....	.....
− 80	−62.2	44	0.85	.....	.....	.....	.....
− 70	−56.7	63	1.22	.....	.....	.....	.....
− 60	−51.1	89	1.72	.....	.....	.....	.....
− 50	−45.6	125	2.41	.....	0.669	5.58	41.8
− 40	−40.0	171	3.30	.....	0.663	5.53	41.4
− 30	−34.4	230	4.44	.....	0.657	5.48	41.0
− 20	−28.9	300	5.80	.....	0.651	5.43	40.6
− 10	−23.3	388	7.50	.....	0.645	5.38	40.3
0	−17.8	489	9.45	.....	0.639	5.33	39.9
10	−12.2	615	11.9	.....	0.633	5.28	39.5
20	− 6.7	760	14.7	0.0	0.627	5.23	39.2
30	− 1.1	941	18.2	3.5	0.621	5.18	38.8
32	− 0	972	18.8	4.1	0.619	5.16	38.7
40	4.4	1148	22.2	7.5	0.614	5.12	38.3
50	10.0	1390	26.9	12.2	0.608	5.07	37.9
60	15.6	1670	32.3	17.6	0.601	5.01	37.5
70	21.1	2000	38.7	24.0	0.595	4.96	37.1
80	26.7	2390	46.2	31.5	0.588	4.90	36.7
90	32.2	2840	54.9	40.2	0.581	4.85	36.3
100	37.8	3365	65.1	50.4	0.575	4.80	35.9
110	43.3	3970	76.8	62.1	0.568	4.74	35.5
120	48.9	4660	90.2	75.5	0.562	4.69	35.1
130	54.4	5450	105.4	90.7	0.555	4.63	34.7
140	60.0	6340	122.7	108.0	0.549	4.58	34.3

THIS discussion of the properties of isobutylene is a part of a bulletin prepared by the Mellon Institute, Pittsburgh, for Pittsburgh-Des Moines Steel Company. In considering requirements for storing this gas it was necessary to present additional data which has been authorized for this presentation.

The research work was done under the direction of Dr. James B. Garner, whose assistants were Ludwig Adams and Robert M. Stuchell.

According to the Baruch report[8] the estimated production of butyl rubber for 1943 is 62,000 long tons and for 1944 is 132,000 long tons.

Methods of Preparation of Isobutylene

(1) *Isobutane Method.* Isobutane (from natural and refinery gases) when heated to 600° C. decomposes mainly into isobutylene. The by-products are hydrogen with some methane and ethylene. The following method is used in isolating the pure substances: dilute sulphuric acid reacts with the other compounds in the mixture. The tertiary butyl sulphuric acid formed is a liquid and is readily hydrolized by means of hot water or dilute alkalis into tertiary butyl alcohol. Tertiary butyl alcohol dehydrates when heated with dilute sulphuric acid and yields pure isobutylene[9].

The catalytic isomerization or transformation of normal butane into isobutane is of great importance in providing adequate supply of isobutane. Large quantities of normal butane are available in natural and refinery gases and are therefore of unusual economic values both for the production of synthetic rubber and high fuels.

(2) *Isobutyl Alcohol Method.* Isobutyl alcohol (a substantial by-product of ethyl alcoholic fermentation and synthetic methanol) when heated with pure aluminum oxide (free of acid) yields isobutylene. (Ipatiev, 1903).[10]

(3) *Tertiary Butyl Alcohol Method.* Tertiary butyl alcohol (a large supply is available from cracking oil refinery gases) when heated with dilute inorganic acids yields isobutylene. This method is in every way similar to that development by Butlerow in 1868.

The isobutylene, as produced, is a gas and must be compressed and cooled to liquefy it. It is transported, stored, and used most economically in the liquid state.

It can be readily concluded from the above paragraphs that there are simple raw materials for the production of isobutylene, namely from manufactured gas, petroleum refineries, natural gas systems,

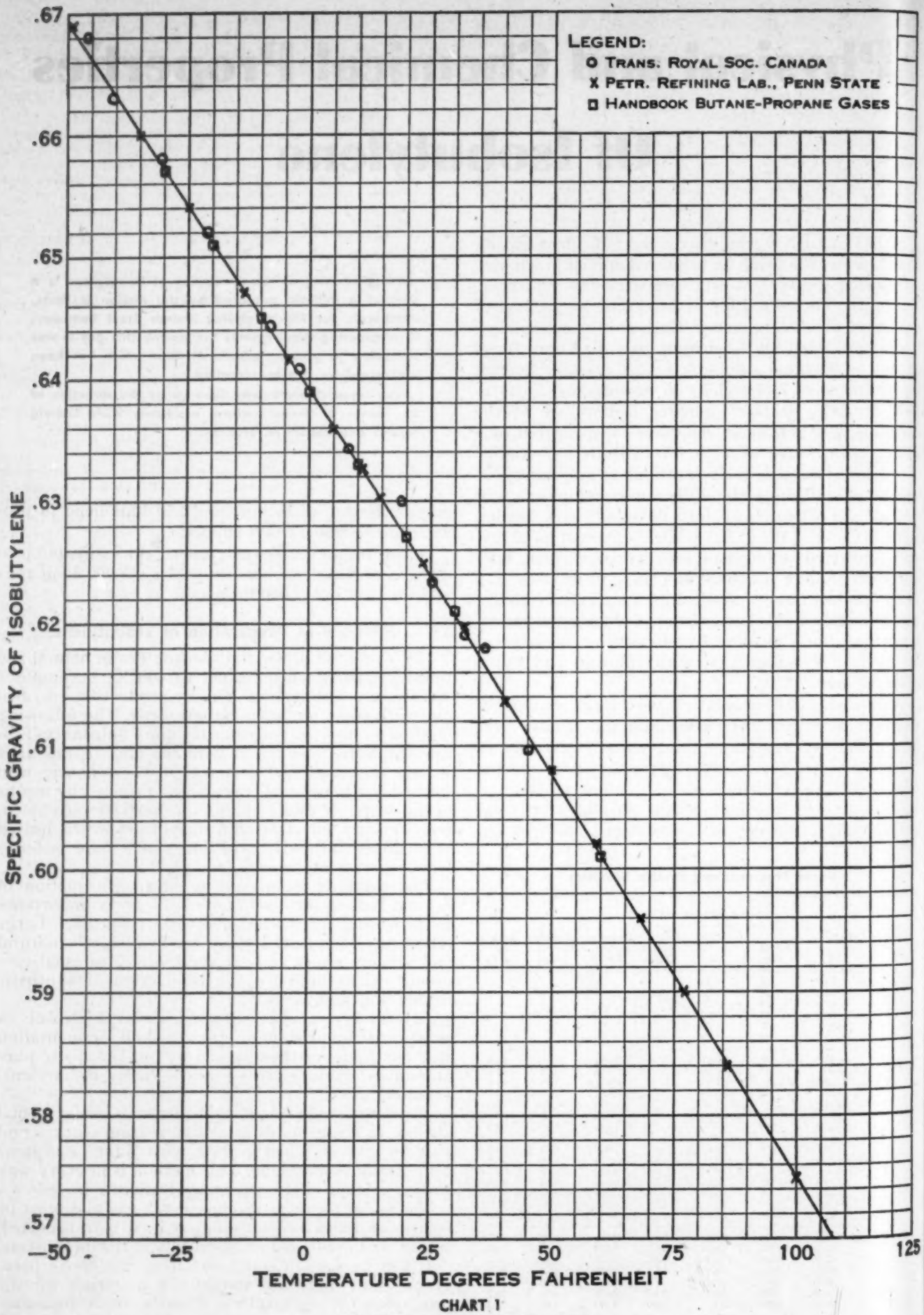


CHART 1

Specific gravity of isobutylene liquid

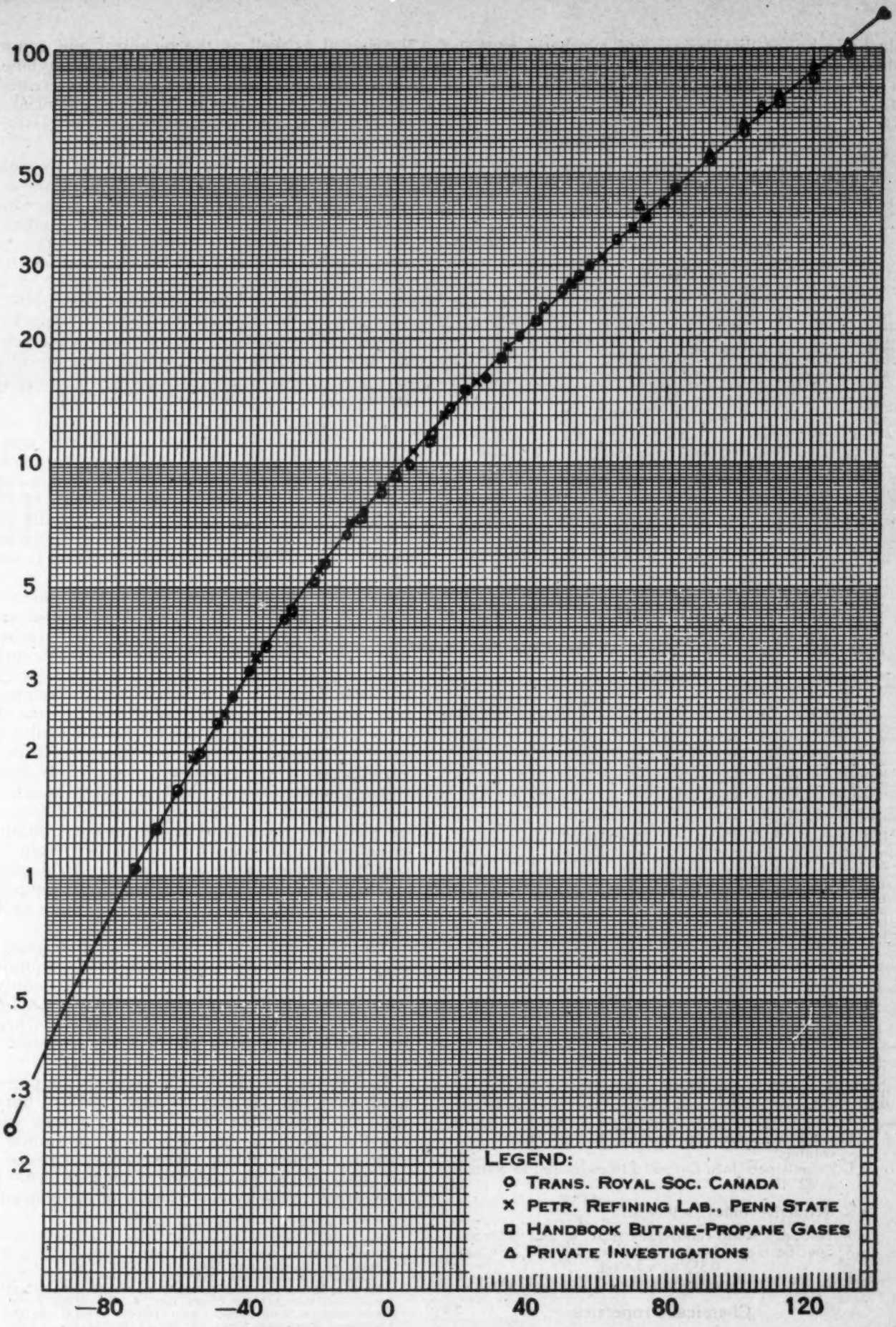


CHART 2

Vapor pressures of isobutylene

alcoholic liquor distilleries, and synthetic methanol plants.

Physical Properties

$$CH_3$$
$$|$$
$$CH_3 - C = CH_2;\ C_4H_8.$$

1. Formula: $CH_3 - C = CH_2$; C_4H_8.
2. Molecular Weight: 56.10.
3. Normal Physical State: Gas, colorless, odorous.
4. Boiling Point as a Liquid: +20.1° F. at 14.7 lbs./sq. in. abs.[11, 12]
5. Melting Point as a Solid: —232.2° F.[11]
6. Specific Gravity as a Gas: 2.011, where air = 1.0.
7. Specific Gravities as a Liquid: Table 1.[11] Also see Chart 1.

TABLE 1

°C.	°F.	Specific Gravity (Water at 0°C. = 1)
—48.9	—56.0	0.6738
—46.9	—52.5	76.10
—44.1	—46.3	.6680
—40.4	—40.8	.6632
—34.8	—30.7	.6581
—29.7	—21.5	.6520
—22.5	— 8.5	.6444
—19.1	— 2.4	.6408
—13.5	+ 7.7	.6343
— 9.5	+18.9	.6299
— 3.7	+25.3	.6234
+ 0.1	+32.2	.6190
+ 2.3	+36.1	.6179
+ 7.3	+45.1	.6095
+11.5	+62.7	.6058

8. Coefficient of Expansion: 0.001872/C.° between —17.8° C. and 10.0° C.[12] (or 0.00104/F.° between 0° F. and 50° F.).[12]
9. Critical Pressure: 582 lbs./sq. in. abs.
10. Critical Temperature: +292.5° F.[12]
11. Critical Density: 0.234.[12]
12. Vapor Pressures:[11] Table 2. Also see Chart 2.

TABLE 2

°C.	°F.	MM. Mercury	Lbs./Sq. In. Abs.
—79.1	—110.4	12.5	0.242
—59.3	— 74.6	53.5	1.038
—55.7	— 68.3	66.9	1.298
—52.5	— 62.5	82.7	1.605
—48.9	— 56.0	101.9	1.977
—46.0	— 50.8	121.1	2.351
—43.5	— 46.3	139.2	2.705
—41.0	— 41.8	161.6	3.135
—38.3	— 36.9	185.3	3.600
—35.3	— 31.5	216.0	4.190
—30.7	— 23.2	265.1	5.140
—29.0	— 20.2	293.9	5.700
—25.5	— 13.9	345.3	6.700
—22.6	— 9.0	390.9	7.595
—20.0	— 4.0	437.5	8.490
—16.4	+ 4.1	510.9	9.900
—12.0	10.4	610.9	11.75
— 8.8	15.6	695.8	13.50
— 6.6	20.1	760.0	14.70
— 6.0	21.2	778.7	15.11
— 4.6	25.9	826.0	16.02
— 2.3	28.8	903.0	17.51
+ 1.8	35.3	1044	20.27
3.5	38.3	1114	21.60
5.9	42.6	1213	23.55
8.8	47.8	1340	26.00
11.4	52.5	1454	28.25
13.0	55.4	1535	29.80
17.4	63.3	1780	34.53
22.1	71.8	2017	39.10

13. Explosive Limits in Air: 1.70 to 9.00 percent by volume.[10]
14. Pounds per U. S. Gallon: 5.16 compared to water at 32° F.
15. Refractive Index: 1.3814 at $\frac{-13° F.}{D}$
16. Viscosity: .0073 centipoises at 32° F. and 972 mm.
17. Specific Heat: 0.366 at 68° F. to 284° F.[12] as a gas. 0.555 as a liquid.
18. Latent Heat of Vaporization: 172.5 BTU per lb.[12]

Chemical Properties

Isobutylene is a very reactive hydrocarbon and it has been the subject of extended research. A list of 68 references during the period of 1825 to 1941 inclusive has been prepared. These references cover the theoretical as well as the technical and commercial developments of the chemistry of isobutylene. This list is herewith submitted for those interested. Isobutylene is an important industrial chemical in the production of synthetic materials[9]—alkylates, polygasolines, resins, and synthetic rubber.

Isobutylene does not oxidize in air to yield peroxides such as is the case with butadiene and styrene. The reaction of isobutylene with chlorine does not yield the dichloride but does yield, depending upon conditions, substitution products—isocrotyl chloride, boiling point 68° C. (154.5° F.) and methyl allyl chloride, boiling point 72° C. (161.6° F.). The latter substance is made in commercial quantities by Shell Oil Company. Isobutylene with hypochlorous acid yields isobutyl chlorhydrin which on treatment with dilute alkalies gives isobutylene glycol. The glycol in the presence of dilute acids undergoes molecular rearrangement and yields isobutylaldehyde.

Isobutylene in the presence of various catalysts such as phosphoric acid, boron trichloride and boron trifluoride, adds to isobutane (from n-butane by isomerization) to form the high-octane gasoline or alkylation stock.

Isobutylene in the presence of an acidic catalyst reacts with primary or secondary alcohols to form mixed ethers. This characteristic reaction is useful in removing it from the other butanes.

In the presence of certain acid and silicate catalyzers, isobutylene is converted into polymers containing from two to seven and even more isobutylene units. A catalyst like aluminum chloride produces polymers with varying high molecular weights. It has been found that by controlling the temperature, polymers varying in molecular weight from di- and tri-polymers to as high as 300,000 molecular weight can be prepared. The physical characteristics of the various polymers range from viscous oily liquids to rubbery materials and finally to white, tough, elastic solids.[14] Generally speaking these polymers of isobutylene are linear and hence do not contain olefin groupings. These polymers have not been vulcanized.[14] However, they have fine electrical properties and maintain these electric properties at temperatures as low as —50° C. (—58° F.) and as high as 100° C. (212° F.).

The reactions which isobutylene undergoes in the presence of varying concentrations of sulphuric acid result in the production of di- and tri-isobutylenes. Both of these polymers contain olefine groupings and hence are not linear. The di-isobutylene when catalytically hydrogenated yields iso-octane or 2,2,4-trimethyl pentane.

Isobutylene reacts with benzene in the presence of aluminum chloride and produces tertiary butyl benzene. A comparable reaction takes places with metaxylene. Both of these reactions are similar to the reaction which takes place between benzene and ethylene in the production of styrene. The trinitro derivative of the xylene compound is artificial musk.

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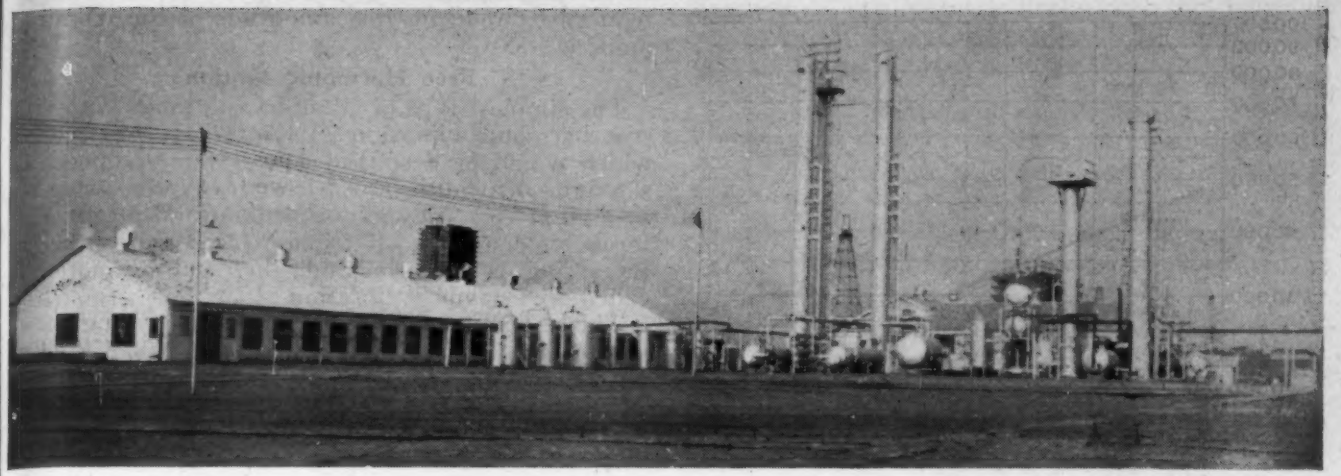


Vibration in Compressor-Plant Piping

M. L. ARNOLD,* Richfield Oil Corporation

USE of compression equipment at high rotative speeds and high operating pressures has made many of us uncomfortably aware of a phenomenon called vibration, which arises specter-like and imparts the shakes to piping, designers, and operators. After once having been responsible for a condition of this kind, engineers dream of designing a plant which is entirely free of vibration.

The purpose of this paper is to describe the avenues by which the engineer may be able to approach this Utopia. But first, we will briefly discuss the mechanical effect of vibration on piping, the mechanics of vibration, and the origin of the forces causing vibration in compressor-plant piping.

If piping is subjected to a stress statically applied, it will rupture only if the stress exceeds the ultimate tensile stress of the metal composing the pipe wall. However, if the pipe is subjected to repeated bending, such as occurs during vibration, rupture may occur even though the maximum stress in the metal has been far less than the ultimate tensile stress. Rupture of this type is referred to as fatigue failure.[1]

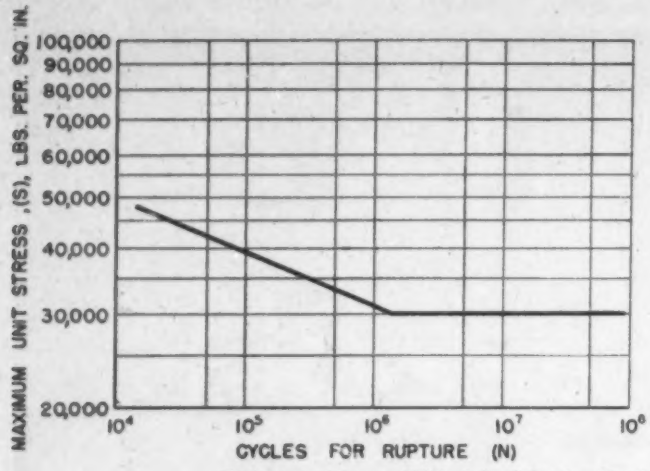
In general, fatigue failure due to vibration is most likely to occur in highly stressed portions of the piping system, such as expansion bends, than in less stressed portions of the piping system, such as straight runs. Failure will occur earlier if the magnitude, or amplitude, of the vibration is large than if the amplitude is small. It will occur at points where non-uniformities such as notches or changes in cross section occur, rather than in uniform sections of piping.

* Presented at the December 7, 1944, monthly meeting, California Natural Gasoline Association.

Some of these points are illustrated in Figures 1, 2, and 3. Figure 1 shows that the number of times a piece of steel can be bent before rupture occurs increases as the maximum bending stress decreases. The stress was varied from that shown on the figure to zero and back during each cycle. Such a curve is called an S-N curve. If a complete reversal of stresses had been effected during each cycle, that is, if the stresses had been varied from a tensile stress to a compressive stress of the same magnitude and back, the S-N curve would be parallel to the one shown, but at each point failure would have occurred at a lesser value of maximum stress. The value of the stress over the horizontal portion of the curve is referred to as the endurance limit of the material.

Figure 2 shows the effect of various types of irregularities in cross sections upon fatigue strength. Irregularities of form such as holes, threads, notches, sharp shoulders, etc., when present in a pipe or other member may produce localized stresses. These stresses may be much greater than the stress calculated by the ordinary formulas of mechanics. For this reason irregularities in section must be considered in estimating the fatigue strength of piping.[2]

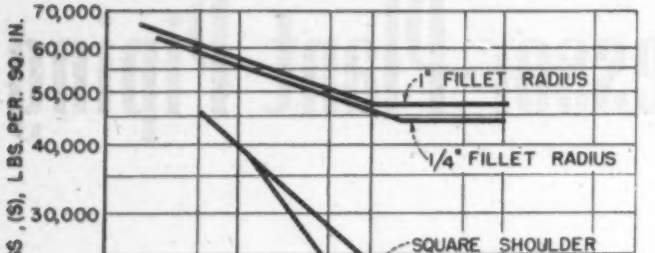
Figure 3 illustrates the effect of maximum stress and stress range upon endurance strength. The ordinate is in percent of the ultimate tensile strength of ferrous metal and the abscissa is arbitrary. It is apparent that if the maximum stress is high, only a small range of stresses can be tolerated during each cycle. If a complete reversal of stresses occurs, the maximum permissible stress is 33 percent of the ultimate tensile stress.[3] If the maximum stress is greater than that shown in the diagram, then the range be-



Reference: Johnson, "Materials of Construction."

FIGURE 1

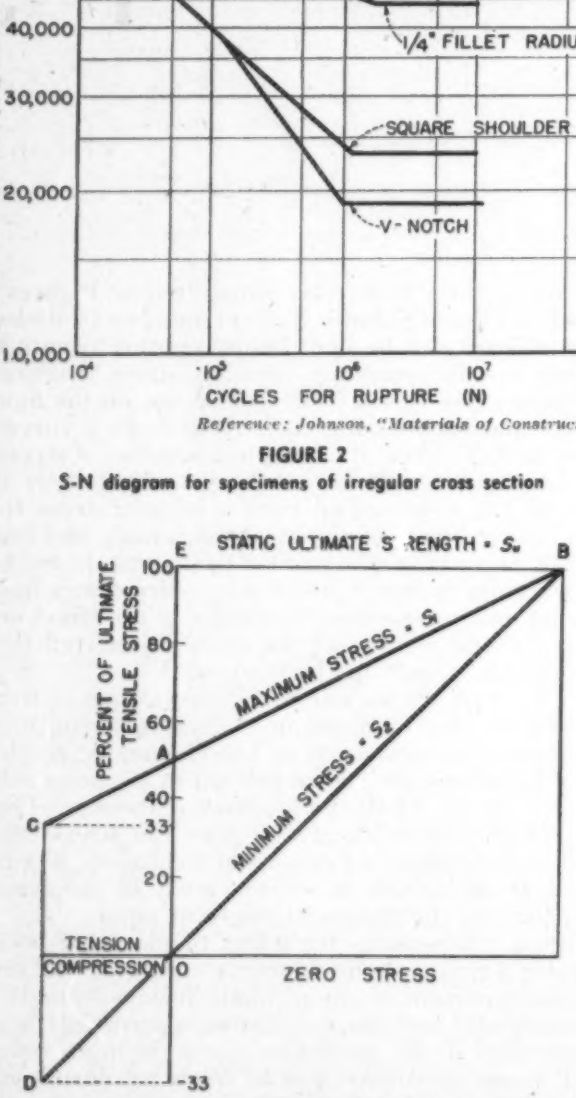
Typical S-N diagram for a ferrous metal



Reference: Johnson, "Materials of Construction."

FIGURE 2

S-N diagram for specimens of irregular cross section



Reference: Johnson, "Materials of Construction."

FIGURE 3

Goodman's diagram—effect of stress and stress range on endurance strength

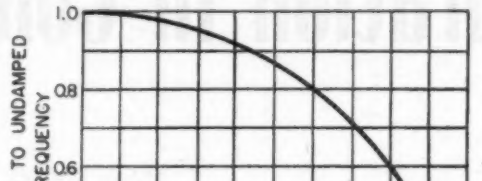
tween the maximum and minimum stress must be reduced by reducing the amplitude of the vibratory motion.

Free Harmonic Motion

The simplest type of vibratory motion is known as free harmonic vibration.[4] It is the type of motion which would be described if a system composed of a weight suspended on a frictionless spring were set in motion in a frictionless medium and no external force acted upon it. If friction is present, either in the spring or in the medium, the resulting motion is called free damped vibration.

The maximum displacement of a vibrating member, such as the weight referred to, is called the amplitude of the vibration. The movement from one position of maximum displacement, through the mean position to the opposite position of maximum displacement and return to the original position is known as a cycle, the time required to complete one cycle as the period, and the number of cycles described per unit of time as the frequency.

If a system capable of vibrating is set in motion, and no retarding forces act upon it, the frequency at



Reference: Den Hartog, "Mechanical Vibrations."

FIGURE 4

Effect of damping on natural frequency of vibration

which it oscillates is known as its natural frequency of vibration. If the motion is retarded (damped), both the amplitude and the frequency of the motion is diminished.

If the retarding force is increased gradually, a value will be found for which the system will not vibrate, but when displaced from its position of rest, will slowly return to this position. The amount of damping just sufficient to effect this is called "critical damping."

The effect of damping on the natural frequency of vibration is given in Figure 4. The ratio of the damped to the undamped natural frequency is shown as a function of the coefficient of damping. This coefficient is defined as the ratio of actual damping to critical damping. For the degree of damping ordinarily experienced, it can be assumed that the natural frequency is not affected.

Forced Damped Vibrations

In compressor plants we are interested, not in free damped vibration, but in forced damped vibrations. Forced damped vibrations result from the action of periodic forces upon a system susceptible to vibration. Examples of such disturbing forces are those

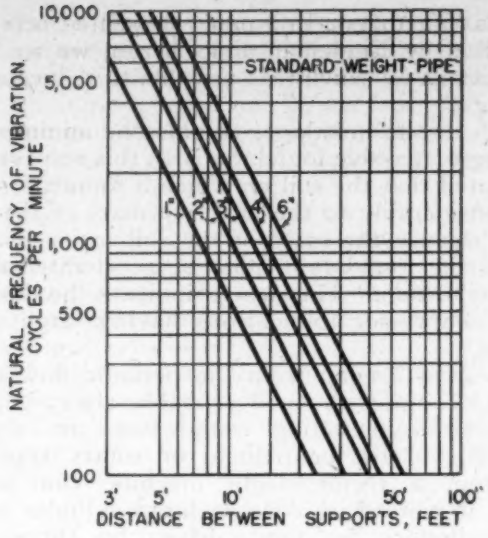


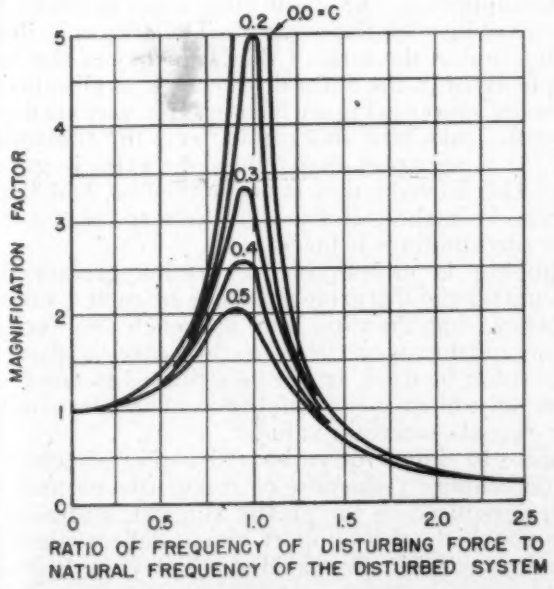
FIGURE 5

Natural frequency of vibration of pipe with supported ends

resulting from the periodic explosions of the charge in power cylinders and from the periodic discharge of gas from a compressor cylinder. If the frequency of the periodic force is the same as the natural frequency of vibration of the system to which it is applied, the periodic force is said to be in resonance with the system.

In general, the preceding remarks, and those which follow, apply to any system in which the static deflection of a member is a linear function of the force applied. A piece of pipe with the ends supported is such a system. Figure 5 shows the natural frequency of vibration of various sizes of pipe supported in this manner, for various distances between supports.

If a force is statically applied to a section of piping supported as described, the deflection can be computed from the usual formulas for deflection of beams. However, when the force is applied periodically, the resulting deflection, or amplitude, may equal, exceed, or be less than the computed static deflection.



Reference: Marks, "Mechanical Engineers Handbook," 4th edition.

FIGURE 6

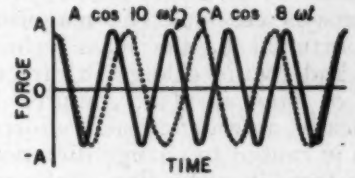
Magnification factor

The ratio between the deflection obtained when the force is applied periodically and the deflection caused by the same force statically applied is called the magnification factor.

This factor is variable with the ratio of the frequency of the applied force to the natural frequency of vibration of the system and with coefficient of damping of the system. The relationship is shown in Figure 6. As shown by the figure, at resonance, a small disturbing force can cause a forced vibration of large amplitude.

Beat Frequencies

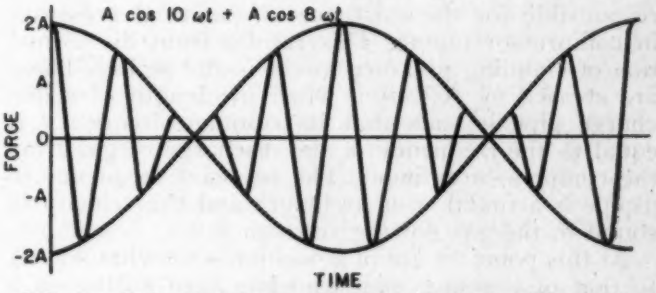
If several disturbing periodic forces act simultaneously on a system, the amplitudes of the forces add algebraically. If the forces are of different frequency, beat frequencies result. For example, if the two periodic forces shown in Figure 7 act simultaneously on a system, the beat frequencies shown in Figure 8 result.



Reference: Freberg and Kemler, "Elements of Mechanical Vibration."

FIGURE 7

Graphical representation of force causing harmonic vibration



Reference: Freberg and Kemler, "Elements of Mechanical Vibration."

FIGURE 8

Beat frequency resulting from simultaneous action of forces shown in Figure 7

The disturbing periodic forces with which we are concerned in compressor plants originate from two sources. These are the rotating and reciprocating parts of the engine and compressor, and the discharge of gas from the compressor cylinders.

The magnitude of the forces created by the moving parts depends largely upon the degree to which these parts have been counterbalanced. The frequency of the force is a function of engine speed and the number of cylinders.

These forces are transmitted as pressure waves through the frame of the engine to the foundation and thence to the surroundings and piping. The pressure waves travel at a speed approximately equal to the velocity of sound in the material through which the wave is being transmitted.[6]

The amplitude of the pressure waves is considerably reduced by damping during transmission. A further reduction in force occurs by reflection when the wave is transmitted from a material in which the velocity of propagation is high to one in which the velocity is lower. For example, at the interface be-

tween the cast-iron bed plate and the concrete foundation, approximately 73 percent of the force of the wave is reflected back into the engine frame. The force is further reduced as the wave passes from concrete to dry earth. Even though these forces are greatly diminished before reaching the piping, they cannot be dismissed as possible causes of vibration. For it has been shown in Figure 5 that at resonance, the magnification factor may approach infinity, and very small forces cause vibrations of large amplitude.

Change in Direction

The disturbance due to the periodic discharge of gas from the compressor cylinder is evidenced principally at points of change in direction of the piping. For when a fluid flowing through a pipe is made to change direction, as at a tee, elbow, or pipe bend, a reactive force is created. The magnitude of this force is proportional to the mass velocity of the flowing fluid and to the change in direction.[8] Since the velocity of flow from a compressor cylinder varies periodically, a periodic reactive force is created when the gas is caused to change direction. The frequency of the force is a function of the speed of the compressor, the number of cylinders connected to the line, the crank angle between the cylinders and whether the cylinders are single or double acting.[9]

This periodic discharge of gas is also sometimes responsible for the existence of abnormal pressures in compressor piping. This results from the formation of standing pressure waves in the piping. These are created by reflection when the length of a discharge pipe is such that its resonant frequency is equal to the frequency of the discharge of gas from the compressor cylinder. The resonant frequency of a pipe is a function of its length and the velocity of sound in the gas flowing through it.[10]

At this point we are in a position somewhat similar to that of a young man who has been sitting on a pier listening to a lecture on the theoretical aspects of swimming, such as the lows of gravity and bouyancy, but who has never been in the water. So suppose we all take a deep breath and prepare to try out some of the theory we have been listening to. But before actually taking the plunge, it might be well to briefly summarize the discussion so far. It can be done as follows:

1. Vibration in compresor-plant piping is caused by periodic forces originating in the compression equipment.
2. These periodic forces are transmitted from the equipment to the piping either through the foundations and surroundings or by means of the flowing gas.
3. The vibration resulting from the application of these periodic forces to the piping is most likely to be destructive if the frequency of the forces is approximately equal to the natural frequency of vibration of the piping.

Solution of the Problem

This summary indicates that there are three avenues of approach to the solution of the problem of designing a compressor plant which will be free of troublesome piping vibration. These avenues are as follows:

1. Design the compression equipment in such a way that all disturbing forces are eliminated.
2. Isolate the sources of disturbing forces from the piping system.
3. Design the piping system in such a way that it will not be affected by any of the periodic forces likely to occur.

These avenues will be explored one by one.

The problem of designing equipment which is free of disturbing forces we will leave to the equipment manufacturers. In a paper presented before the association by Engleman and Chrzan, we were told of the extent to which it is possible to reduce engine unbalance.[5]

Forces due to unbalance can also be minimized by resorting to massive foundations. In this respect it has been stated that the soil on which a foundation rests adds considerably to the effective mass of the foundation because the mass of the soil, as well as the mass of the foundation must be accelerated during lateral vibration.[11] This would indicate the desirability of compressor foundations having large spread footings.

The forces arising from the periodic flow of gas from the compressors will probably always be with us, unless reciprocating compressors are replaced with units of the centrifugal or rotary type. The flow from a reciprocating machine can be improved, if instead of a single large cylinder several small cylinders are used, driven by throws uniformly spaced around the crankshaft. This will decrease the amplitude of the disturbance, but the frequency will be increased.

In other industries much progress has already been made along the second avenue of approach. It has been demonstrated that a source of disturbing periodic forces, such as a gas engine, can be isolated from its surroundings with almost any desired degree of completeness by mounting the machine on elastic supports. For small masses, springs, rubber, corkboard and felt supports are available. For large masses springs, or springs in combination with one of the other materials, are generally used. It is stated that machines weighing up to 450 tons have been satisfactorily isolated in this way.[12]

Buildings have been isolated from vibrations transmitted to foundations by erecting the columns on pads made of alternate layers of lead and asbestos.[13]

Elastic Supports

Great care must be used in designing elastic supports. If improperly designed, the forces transmitted to the surroundings may be magnified rather than reduced.

The ratio of the force transmitted through an elastic support to the disturbing force is called the transmissibility of the support. The transmissibility is a function of the ratio of the frequency of the force being isolated to the natural frequency of vibration of the elastic support. Figure 9 shows, for various damping coefficients, how this ratio affects the transmissibility. It is apparent that unless the ratio is greater than 1.414, no reduction is accomplished, and that if the ratio is in the vicinity of 1, the force transmitted to the surroundings is increased.

Damping is undesirable for ratios greater than 1.414 unless the disturbing force is of such a variable frequency, that the ratio may approach one during a portion of the operation. In this case, a damping device must be used. It can be adjusted to come into action only in case the amplitude of the transmitted force exceeds a certain value.

Figure 10 shows for various disturbing frequencies and percentage reduction of force, the natural frequency required of the elastic support, and also the amount which the support must deflect statically when loaded with the machine which it is desired to isolate.

The theory of elastic engine supports has been discussed at length in a paper by Rosenzweig.[14]

As an alternate to isolating engines from the piping,

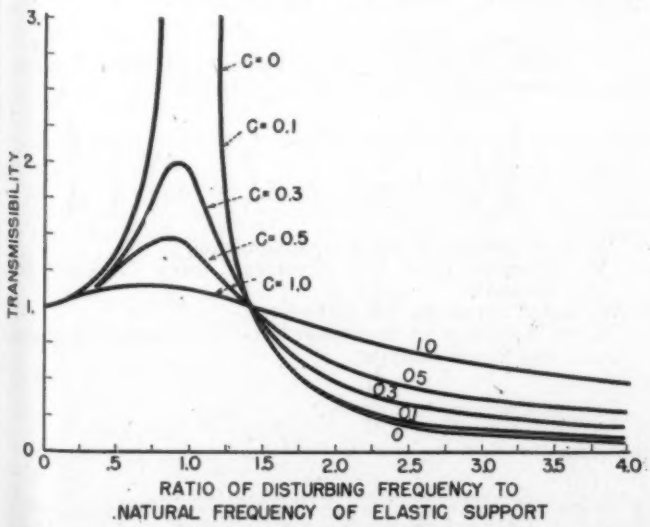
piping can be isolated from the engines. If it is necessary to support piping from the engine foundations or from structures affected by engine vibrations, elastic piping supports can be used. These may be steel springs if the piping is suspended from a structure, and steel springs or rubber if the piping is supported from the foundation.

In this latter case, the piping can also be protected from pressure waves transmitted from the foundation by causing a portion of the force of the wave to be reflected back into the foundation. This is accomplished by interposing between the support and the foundation a layer of material in which the velocity of sound is low as compared to the velocity of sound in concrete. Examples of such materials are rubber, cork, and dry sand. If rubber is used, approximately 80 percent of the force will be reflected back into the concrete.

Changes in Velocity

The problem of isolating pipe bends from changes in velocity of the flowing fluid is more difficult. Some degree of uniformity of flow in the lines to and from the compressors may be attained by the use of apparatus similar to that used to muffle the exhaust from an engine. However, the problem is more difficult. A muffler attempts only to suppress vibrations in the audible sound range while here we are concerned with securing a constant flow velocity. It may be possible to solve the problem by acoustical methods.[16]

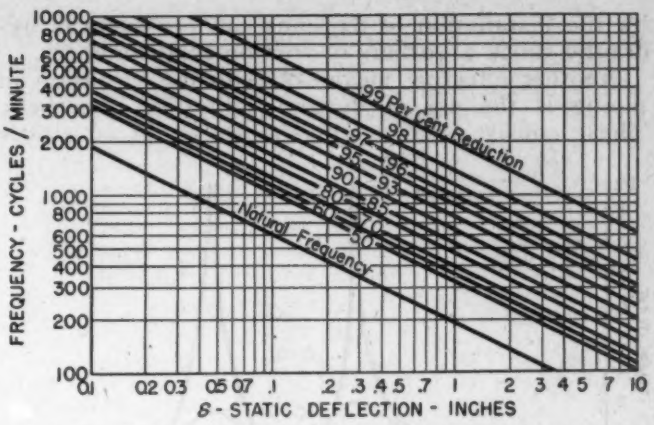
The third and final avenue of approach is careful, intelligent piping design. Supports should be spaced so that no part of the piping system has its natural frequency of vibration equal or nearly equal to the frequency of any periodic force created by the engine or compressor. As was noted in the discussion of Figure 6, if the supports are spaced so that the ratio of the frequency of the disturbing force to the natural frequency of the piping is greater than 1.4, magnification factors of less than 1 can be obtained. This will result in piping which will be almost free of vibration. A disadvantage of designing for ratios in this range is that when an engine is shut down, at some instant before it comes to rest, the frequency of the forces which it emits will be in resonance with the piping. This might cause destructive vibration. While this difficulty can be overcome by installing vibration dampners on the piping, it is probably safer practice



Reference: Freberg and Kemler, "Elements of Mechanical Vibration."

FIGURE 9

Transmissibility of elastic supports



Reference: Freberg and Kemler, "Elements of Mechanical Vibration."

FIGURE 10

Vibration isolation frequency-static deflection chart

to design for ratios of between 0.25 and 0.50, even though this results in magnification factors slightly greater than 1.

Pipe Supports

Particular attention must be given to supporting piping at points where changes in direction occur. At these points, the piping is subject to both the forces eminating from the engine and those set up by the pulsating flow of gas from the compressor cylinders. In case the change in direction is installed for the purpose of securing flexibility, it may be necessary to use springs or other types of elastic supports.

It might be possible to elimiante vibration in expansion bends if they were designed to be symmetrical about an axis coincident with that of the main pipe line. In this case components of pressure in all directions, except the original direction of flow, would neutralize each other.

Lengths of piping between the compressor cylinder and the surge chamber or header, and between surge chamber and header, or between headers, should not be equal to the resonant length for the frequency at which gas pulsates in the line. If resonant lengths cannot be avoided, the magnitude of the standing pressure wave formed can be limited by installing a condenser or surge chamber in the line near the compressor cylinder. The required volumetric capacity of the condenser is a function of the piston displacement of the cylinder, the normal pressure in the line, and the permissible pressure rise.[15]

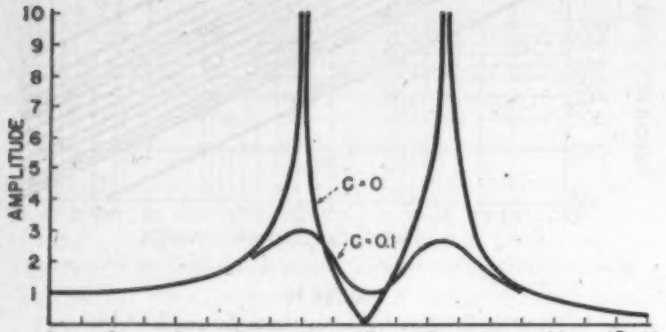
Now, even the best of engineers sometimes make mistakes. Either errors of omission, or the other kind. So it is always well to have a few aces up the sleeve just in case there is a joker somewhere in the design. The standard method of dealing with a vibrating pipe is to install more supports and more and heavier pipe clamps. This is equivalent to increasing the natural frequency of vibration of the piping. The natural frequency of vibration of a section of piping can also be increased by attaching a spring to it. The spring is selected and loaded so that the natural frequency of the spring, load, and piping is sufficiently greater than the disturbing frequency to reduce the magnification factor by the required amount.

Another approach as indicated by the Magnification Factor Chart, Figure 6, is to reduce the number of supports. In this way magnification factors of less than one can be obtained. The hazards of this approach should be kept in mind when it is used.

The amplitude of the vibration can also be limited

by the installation of damping devices such as hydraulic shock absorbers of friction-type snubbers.

Another effective means of reducing vibration in piping is the use of dynamic vibration absorbers. These consist of a weight suspended on an elastic member from the vibrating piping. The natural frequency of the weight and elastic suspension should be the same as the natural frequency of the vibrating member. The relationship between the amplitude of the vibration of the original member in such a system and the ratio of the frequency of the disturbing force to the natural frequency of the compensating systems is shown in Figure 11 for zero damping and for a damping coefficient of 0.10. Inspection of the figure shows that the device cannot be used if the range of disturbing frequencies is too great.



Reference: Freberg and Kemler, "Elements of Mechanical Vibration."

FIGURE 11

Effect of dynamic vibration absorbers

Those remarks practically conclude the paper. Some of you, no doubt, would have appreciated a mathematical presentation of the subject. This was purposely avoided because the mathematics is fully developed in books dealing with special phases of the subject. These books and some of the formulas to be found therein are listed in the appendix.

The principal aim of the paper has been to give you a Cook's tour prospectus of the three avenues of approach to the problem of designing compressor plants which will be free of troublesome piping vibration. It will have been accomplished if you have been encouraged to further explore these approaches.

FORMULAS

A. FATIGUE STRENGTH.

Reference—Johnson: Materials of Construction, Chapter 28.

A formula for determining the maximum permissible unit stress during a cycle is as follows:

$$S_{max} = \frac{0.5\,S_u}{1 - 0.5r}$$

S_u = Ultimate tensile strength of the material.
r = Ratio of minimum to maximum stress during the cycle.

S_u can be replaced by S_w.

$$S_w = \frac{S_u}{\text{Factor of Safety}}$$

Another formula, developed on a different basis is as follows:

$$S_{max} = \frac{2\,S_1}{(1-r) + \frac{S_1}{S_y}(1+r)}$$

S_1 = The endurance limit for completely reversed stresses.
S_y = Yield Strength.

B. VIBRATION.

Reference—Freberg & Kemler: Elements of Mechanical Vibration.

1. *Free Harmonic Vibration.*

The natural frequency of vibration (f_n) of a mass suspended from a spring of negligible mass is

$$f_n = \frac{1}{2\pi}\sqrt{\frac{Kg}{W}}$$

K = Spring constant (lb.)/(in.).
g = Acceleration (in.)/(Sec.)^2 due to gravity.
W = Weight (lbs.).
π = 3.1416.
f_n = Natural frequency of vibration, cycles per second.

The spring constant (K) for two springs in parallel and having constant K_1 and K_2, respectively, is

$K = K_1 + K_2$.

If the same springs operate in series, the constant (K) for the system is

$$K = \frac{K_1\,K_2}{K_1 + K_2}$$

The spring constant is further defined as

$$K = \frac{F}{d} = \frac{W}{d}$$

F = Force in pounds acting on spring.
d = Deflection of spring in inches.

$$d = \frac{W}{K}$$

$$\frac{K}{W} = \frac{1}{d}$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{g}{d}}$$

The natural frequency of vibration of a beam, such as a pipe between supports, can be approximated by computing the maximum deflection due to its own weight and substituting in the above formula. For an exact method see Timoshenko: Vibration Problems in Engineering.

2. *Forced Damped Vibration.*

If a periodic force acts upon a system susceptible to vibration, the amplitude of the resulting vibration is

$$X = \frac{F}{K}\left\{\frac{1}{\left[\left(1-\left(\frac{V}{W_n}\right)^2\right)^2 + \left(2C\frac{V}{W_n}\right)^2\right]^{1/2}}\right\}$$

X = Amplitude of the forced vibration.
V = Frequency of the disturbing force (radians per second).
$W_n = 2\pi f_n$ radians per second.
C = Coefficient of damping = Ratio of actual damping to critical damping.

$$\text{Critical Damping} = 2\frac{W}{g}W_n$$

the term

$$\frac{1}{\left[\left(1-\left(\frac{V}{W_n}\right)^2\right)^2 + \left(2C\frac{V}{W_n}\right)^2\right]^{1/2}}$$

is called the magnification factor and is shown in Figure 6.

3. *Elastic Supports.*

If a vibrating machine is supported on a sub-structure by an elastic medium, the ratio of the force transmitted to the substructure to the disturbing force is.

$$T.R. = \left[\frac{1 + \left(2C \frac{V}{W_n}\right)^2}{\left(1 - \left(\frac{V}{W_n}\right)^2\right)^2 + \left(2C \frac{V}{W_n}\right)^2} \right]^{1/2}$$

T.R. = Transmissibility = Ratio of force transmitted to substructure to disturbing force. This relationship is shown graphically in Figure 9.

4. *Dynamic Vibration Absorber.*

If a body is vibrating it is possible to reduce or eliminate the vibration by suspending from the vibrating body a weight supported by an elastic member. If W_1 and K_1 represent the weight and spring constant of the system in which the vibration is occurring and W_2 and K_2 represent the weight and spring constant of the system suspended from it to control the vibration, then the amplitude of the movement of W_1 is as follows:

$$X_1 = \frac{F}{K_1} \left\{ \frac{1 - \left(\frac{V}{W_{n2}}\right)^2}{\left[1 - \left(\frac{V}{W_{n2}}\right)^2\right]\left[1 + \frac{K_2}{K_1} - \left(\frac{V}{W_{n1}}\right)^2\right] - \frac{K_2}{K_1}} \right\}$$

$$W_{n1} = \left(\frac{K_1 g}{W_1}\right)^{1/2}$$

$$W_{n2} = \left(\frac{K_2 g}{W_2}\right)^{1/2}$$

This function is shown graphically in Figure 8. When $V = W_{n2}$, the amplitude of the motion of W_1 may be reduced to zero by making $\frac{K_2}{W_2} = \frac{K_1}{W_1}$, or since $\frac{K}{W} = \frac{1}{d}$, this may also be expressed as $\frac{1}{d_2} = \frac{1}{d_1}$.

The amplitude of motion of W_2 is

$$X_2 = \frac{F}{K_1} \left\{ \frac{1}{\left[1 - \left(\frac{V}{W_{n2}}\right)^2\right]\left[1 + \frac{K_2}{K_1} - \left(\frac{V}{W_{n1}}\right)^2\right] - \frac{K_2}{K_1}} \right\}$$

C. Propagation of Pressure Waves.

Reference—Thornton: Mechanics Applied to Vibration and Balancing, Chapter 4.

The rate of propagation of pressure waves through an elastic medium is $a = \left(\frac{Eg}{d}\right)^{1/2}$

a = Rate of propagation of disturbance (ft.)/Sec.
E = Modulus of Elasticity of medium (lbs.)/(ft.)^2
g = Acceleration of gravity (ft.)/(Sec.)^2
d = Density (lbs.)/(ft.)^3

This is sensibly the velocity at which sound is propagated in the material.

At the interface between two materials having dissimilar values of a, a portion of the stress due to pressure waves will be reflected back. If P_A is the stress due to the original wave, then the reflected stress will be

$$P_B = \left[\frac{(E_2 d_2)^{1/2} - (E_1 d_1)^{1/2}}{(E_2 d_2)^{1/2} + (E_1 d_1)^{1/2}} \right] P_A$$

the transmitted stress is

$$P_C = \frac{2 P_A}{1 + \left(\frac{E_1 d_1}{E_2 D_2}\right)^{1/2}}$$

Subscript 1 refers to the medium from which the stress is being transmitted. Subscript 2 refers to the medium to which the stress is being transmitted. A negative value indicates that the reflected or transmitted stress produces a state of tension.

D. Pressure Due to Deviated Flow.

Reference—Marks: Mechanical Engineers Handbook, 4th Edition, Page 279.

If the direction of flow of a stream is changed, the pressure or thrust in the direction before turning is

$P = (Qw\ V/g)\ (1 - \cos B)$
Q = Quantity flowing per second.
w = Weight of unit volume of fluid.
V = Velocity of fluid.
g = Gravity acceleration constant.
B = Angle through which flow is deviated, measured from direction before turning.

The total resultant pressure is
$P = (QwV/g)\ [2(1 - \cos B)]^{1/2}$

The direction of the resultant force is 90° from midway between the original and final direction of the flowing liquid.

E. Resonant Length of Pipes.

Reference—Olson: Elements of Acoustical Engineering, Page 47.

The fundamental resonant frequency of a pipe open at both ends is $f = \frac{a}{2L}$

If the pipe is closed at one end $f = \frac{a}{4L}$

f = resonant frequency in cycles per sec.
a = velocity of sound in gas in ft. per sec.
L = length of pipe in feet.

In the case of a pipe closed at one end, such as between a compressor cylinder and surge chamber or header, lengths corresponding to the fundamental frequency should be avoided, and if possible the second harmonic.

In the case of a pipe open at both ends, such as between a surge chamber and a header, or between two headers, lengths corresponding to the fundamental and, if possible, the third harmonic, should be avoided.

F. Weight of Foundation.

Reference—Slocum: Noise and Vibration Engineering, Page 44.

The weight of a foundation which will result in a given amplitude of the lateral motion b of a foundation and reciprocating machine of horizontal type is given as follows:

$$W_4 = \frac{r}{b(1+K)} \left[W_1 + W_2 \left(1 + \frac{1}{q}\right) \right] - \frac{W_3}{1+K}$$

W_4 = Weight of foundation.
W_3 = Total dead weight of engine—lbs.
W_2 = Weight of reciprocating parts—lbs.
W_1 = Weight of eccentric rotating parts—lbs.
r = Crank radius in inches.
b = Amplitude of vibrating motion—inches.
q = Length of connecting rod/length of crank.
k = Ratio of mass of soil accelerated to mass of foundation. In the example given, the factor was assumed to be 10.

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Application of Unit Operations to

Fractionation and Other Vaporization Processes

PART 13

Illustrative Exercises and Problems

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A REVIEW of the twelve previous papers of this series can best be made by solving several typical exercises which illustrate the principles set forth. A distinction is made between exercises and problems in that the exercise is far more simple than the problem, the latter being so complicated in nature that a number of simplifying assumptions usually are set up before even an attempt is made at the solution. A problem in the strict sense appears to be so involved at first sight that no solution can be obtained readily. Furthermore no two engineers, working independently, will come out with the same solution, in view of the wide variety of viewpoints and assumptions expressed by technical men. The problem method of instruction is often somewhat slow and painful but it is the soundest one for the engineering student to follow.

Differential Versus Equilibrium Flash Vaporization

In one paper the author has briefly explained the nature of these two vaporization processes. Each process has its place to fill in the industrial plant, depending upon the particular situation at hand or the special product to be manufactured. The differential or batch method is one in which the evolved vapor is removed from the vessel as soon as it is formed, the temperature being raised continuously with a constant pressure or the pressure being lowered gradually at constant temperature. Other terms such as "unsteady state," "transient" or "non-flow" might also be used to describe this differential process.

The equilibrium flash vaporization is one in which all the evolved vapor is in close contact with its residual liquid at all times. The pipe still and flash chamber, operating under steady state flow conditions is the most common type of apparatus falling within this type of process. Although the pressure and temperature may vary from point to point in the equipment, the conditions at any one point remain constant from hour to hour.

A combination of these two processes is found in the conventional stage-separation method of recovering crude oil and distillates from oil and gas reservoirs. This method is differential in that the release of gas takes place at various pressure levels, however it is equilibrium flash in so far as the process follows the steady flow into and out of each separator in the system.

Piromov and Beiswenger[3] have simplified the determination of a flash vaporization curve for any typical crude oil establishing an empirical relationship between the true boiling point or differential vaporization and the "flash" vaporization curve. They found that over a large part of the distillation range, the "flash" yields a higher vaporization for the same temperature.

The difference between a batch and a continuous distillation can best be brought out by an illustration such as the following exercise:—

A mixture consisting of 40 mol percent propane and 60 mol percent normal butane is subjected to a batch distillation at a constant pressure of 100 pounds per square inch absolute until 50 mol percent of the blend is taken off as vapor overhead from the still.

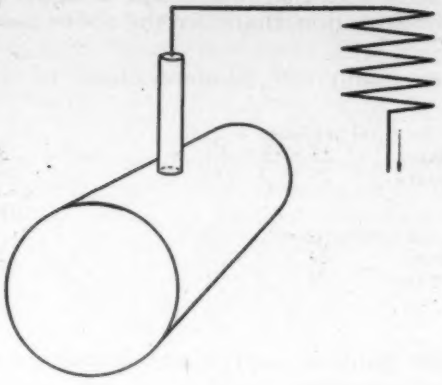
(a) What will be the initial and final temperatures required to effect this batch operation? Figure 1(A).

(b) If the above mixture is heated in a pipe coil and "flashed" under equilibrium vaporization conditions in a vessel at a pressure of 100 pounds per square inch absolute. What temperature will be required in the vessel and its contents to bring about 50 mol percent vaporization? Figure 1(B).

Solution:

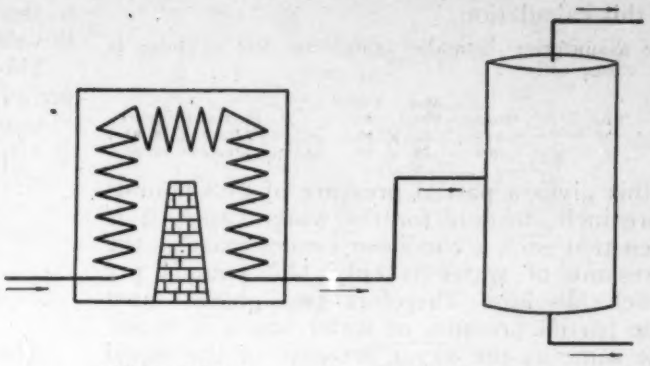
Part (a)

For this batch operation, a complete derivation of Rayleigh's equation is given in Walker, Lewis, and McAdams Principles of Chemical Engineering.[4] The initial temperature required to start vaporization (or the bubble point) is determined by the cut and try method and found to be approximately 95° F. The calculation is made on the basis of 100



BATCH STILL

FIGURE 1 (A)
Differential vaporization



PIPE STILL

FLASH DRUM

FIGURE 1 (B)
Flash vaporization

mols of charge to the still. The term α is the relative volatility of propane to that of normal butane, or the ratio of their respective vapor pressures; L_1 and L_2 are the number of mols of feed and residue respectively. X_1 and X_2 are the corresponding mol fractions of propane in the feed and residue.

Part (a)

	Mol V.P. Frac.	Partial pressure in liquid	
$C_3 = 179 \times .4 =$	71.6	}	at 95° F.
$C_4 = 50 \times .6 =$	30.0	}	
	101.6		

$\alpha = 3.52 \quad L_1 = 100 \quad L_2 = 50 \quad X_1 = .40 \quad X_2 = ?$

$$\ln_e \frac{L_1}{L_2} = \frac{1}{\alpha - 1} \ln_e \left[\frac{X_1 \ (1-X_2)}{X_2 \ (1-X_1)}\right] + \ln_e \left[\frac{1-X_2}{1-X_1}\right]$$

$$\ln_e 2 = \frac{1}{2.52} \ln_e \left[\frac{0.4(1-X_2)}{X_2(0.6)}\right] + \ln_e \frac{(1-X_2)}{0.6}$$

$$2.52 \ln 2 = \ln_e 0.667 \left[\frac{1-X_2}{X_2}\right] + 2.52 \ln \left[\frac{(1-X_2)}{0.6}\right]$$

$$2.52 \ln 2 = \ln_e 0.667 + \ln \left[\frac{1-X_2}{X_2}\right] + 2.52 \ln(1-X_2) - 2.52 \ln(0.6)$$

$$1.75 + 0.406 = \ln \left[\frac{(1-X_2)\ (1-X_2)^{2.52}}{X_2}\right] =$$

$$\ln \left[\frac{(1-X_2)^{3.52}}{X_2}\right] = 0.864 \left[\frac{(1-X_2)}{X_2}\right]^{3.52} = 2.37$$

[Residue]

Final Temp. = 116°F. $\quad X_2 = 0.195$ or $X_2 = .195$ (C_3 in liquid)
$X_4 = .805$ (C_4 in liquid)

Part (b)

$$100y_3 = p_3x_3$$
$$100y_4 = p_4x_4$$
$$0.4 = 0.5x_3 + 0.5y_3$$
$$x_3 + x_4 = 1$$
$$y_3 + y_4 = 1$$

$$p_3 = \frac{100y_3}{x_3} \qquad p_4 = \frac{100y_4}{x_4} \qquad \frac{p_3}{p_4} = 3.46 = \frac{y_3x_4}{y_4x_3} = \alpha$$

$$3.46 = \frac{x_4(1-y_4)}{y_4(1-x_4)} \qquad y_4 = \frac{0.6 - 0.5x_4}{0.5} = 1.2 - x_4$$

$$3.46 = \frac{x_4(1-1.2+x_4)}{(1-x_4)\ (1.2-x_4)} = \frac{0.2x_4 + x_4^2}{1.2 - 2.2x_4 + x_4^2}$$

$$4.15 - 7.61x_4 + 3.46x_4^2 = 0.2x_4 + x_4^2$$
$$2.46x_4^2 - 7.41x_4 + 4.15 = 0 \qquad x_4^2 - 3.01x_4 + 1.685 = 0$$

$$x_4 = 3.01 \pm (9.06 - 6.15)^{1/2} = \frac{3.01 - 1.52}{2} = .745 \text{ (mol. frac. of}$$

normal butane in residue.)

$p_3 = 214 \qquad t_3 = 108°$
$p_4 = 61 \qquad t_4 = 108°$

Batch vaporization would therefore require a higher temperature to effect 50 percent vaporization.

The Physical State of a System

The phase rule is a very useful generalization when one wishes to determine the physical state of certain materials confined in a vessel under a fixed temperature and pressure.

The following set of exercises are suggested as a test of one's ability to determine the state of a system.

In each of the following cases, determine the physical state of the chemical compounds present in a cylinder equipped with a frictionless piston and if possible the mol fraction of each compound in each phase. State any simplifying assumptions you may see fit to make, giving your reason for doing so.

(a) 2 pounds each of water and air at 212° F. and 16 pounds per square inch absolute.

(b) 2 pounds each of water and air at 212° F. and 40 pounds per square inch absolute.

(c) 1 pound mol each of normal butane and normal pentane at 100° F. and 50 pounds per square inch absolute.

(d) 1 pound mol each of NC_4 and NC_5 at 100° F. and 20 pounds per square inch absolute.

(e) A mixture of NC_4 and NC_5 at 100° F. and 28 pounds per square inch absolute.

(f) What is the dew point of a mixture consisting of 1 pound of steam and 3 pounds of NC_5 vapor? The pressure is to be held constant at 10 pounds per square inch absolute? What is the composition of the first drop of condensate? What is the bubble point for the water-pentane mixture? At what temperature will pentane start to condense?

Solution:

(a) It is easily seen that some vaporization will take place since air under these conditions is so slightly soluble in water; furthermore, the water is under a total pressure only a little above its vapor pressure. It is assumed at first that the mixture is totally vaporized, in order to determine the partial pressure of each component in the vapor phase.

	Lbs.	Lb. Mols.	Mol. Frac.	Total Pr.		Partial Pressure In Vapor
Water	2 ÷ 18	= .111	.62	× 16	=	9.9 lbs./sq. in. abs.
Air	1 ÷ 29	= .069	.38	× 16	=	6.1 lbs./sq. in. abs.
		.180	1.00			16.0

The assumption is valid since the partial pressure of the water vapor is less than the vapor pressure of water, making it impossible for liquid water to exist

in the cylinder. The solubility of air in water is neglected in this calculation.

(b) The assumption is made again that the cylinder is filled with vapor only.

	Lbs.	Mols.	Mol. Frac.	Total Pr.		Partial Pressure
Water	2	.111	.62 ×	40	=	24.8 lbs./sq. in. abs.
Air	2	.069	.38 ×	40	=	15.2 lbs./sq. in. abs.

Since this gives a partial pressure of 24.8 pounds per square inch absolute for the water vapor, it is easily seen that such a condition cannot exist as the vapor pressure of water is only 14.7 pounds per square inch absolute. Therefore two phases must exist. The partial pressure of water vapor is necessarily the same as the vapor pressure of the liquid water when equilibrium exists. The vapor above the water consists of:

	Partial Pressure	Vol. or Mol. Fraction
Water vapor	14.7 lbs./sq. in.	.367
Air	25.3 lbs./sq. in.	.633
		1.000

(c)

If the total pressure in the cylinder is greater than the vapor pressure or bubble point of the mixture, the two hydrocarbons would be in liquid form.

	Vapor pressure		Mol frac. in liquid		Partial pressure
Normal butane	53	x	.5	=	26.5
Normal pentane	16	x	.5	=	8.0
					34.5 total vapor pressure

The mixture would therefore be in liquid form.

(d)

It is assumed that the mixture is all vapor.

By Raoult's law:

	π	$y = p$	x	
N butane	20	.5 = 53	x_4	$x_4 = .188$
N pentane	20	.5 = 16	x_5	$x_5 = .625$
				.813

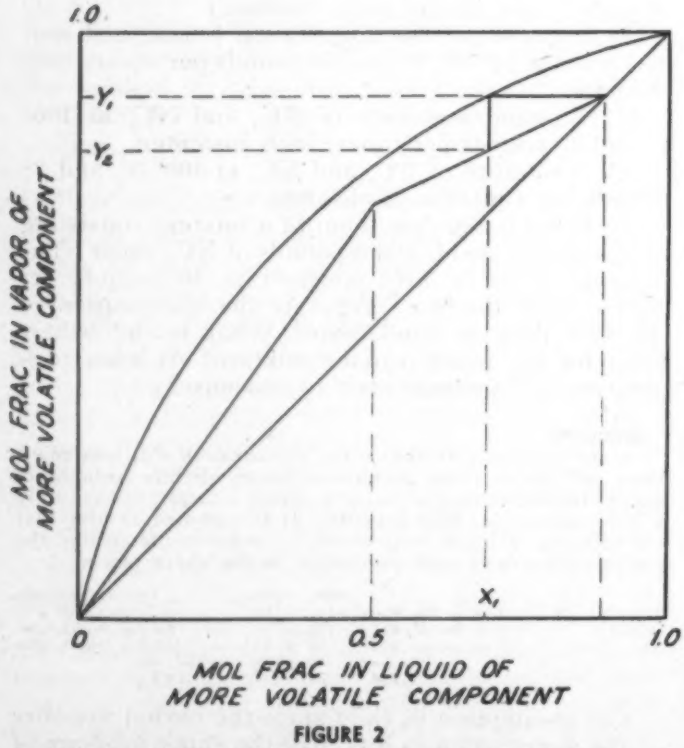


FIGURE 2

Fractionation of a Binary Mixture in an actual tower. (Comparison of liquid and vapor composition around a plate.)

It is readily seen that it will take a higher pressure to start condensation, therefore the above assumption is valid.

The dew point can be determined by trial and error.

Assume the total pressure = 25 lb.

N butane	$25 \times .5 = 53$ x_4	$x_4 = .236$
N pentane	$25 \times .5 = 16$ x_5	$x_5 = .780$
		1.016

Assume the total pressure = 24 lb.

N butane	$24 \times .5 = 53$ x_4	$x_4 = .226$
N pentane	$24 \times .5 = 16$ x_5	$x_5 = .750$
		.976

The dew point is approximately 24.5 pounds per square inch absolute.

(e) Since 28 pounds pressure is between the 24.5 pounds dew point and 34.5 pounds bubble point, the mixture must be part vapor and part liquid. The composition of each phase can be determined as follows:

		π	$y = p$	x
(1)	N butane	28	$y_4 = 53$	x_4
(2)	N pentane	28	$y_5 = 16$	x_5
	Since $y_4 + y_5 = 1$ and $x_4 + x_5 = 0$, we can rewrite equation (2)			
(3)	N pentane	$28(1-y_4) = 16(1-x_4)$		

Adding (1) and (3)

$$28 = 16 + 37\,x_4$$

Liquid = { $x_4 = .324$ (N butane), $x_5 = .676$ (N pentane) } 1.000

Vapor = { $y_4 = .614$ (N butane), $y_5 = .386$ (N pentane) } 1.000

(f)

The dew point for two components which are immiscible in the liquid state cannot be determined by Raoult's law, since each component exerts its own vapor pressure independent of the other.

	lbs.	lb/mol = lb mols	mol frac		Total Pr		Partial pressure
Water	$1 \div 18 = .0555$	.57	×	10	=	5.7
N pentane	$3 \div 72 = .0417$	.43	×	10	=	4.3
	.0972	1.00				

Referring to a standard set of steam tables, it is found that water has a vapor pressure of 5.7 pounds at 168° F. The first drop of condensate will therefore be water.

The bubble point or vapor pressure of the mixture will be the temperature at which the sum of the vapor pressures will equal 10 pounds per square inch absolute. By trial and error, this temperature is found to be 75° F. (approximately).

	vapor pressure
Water =	0.43 lbs./sq. in. abs.
N pentane =	9.57 lbs./sq. in. abs.
	10.00

As the temperature is lowered below 168° F., steam continues to condense out of the vapor, causing the partial pressure of the normal pentane to rise. When a temperature of 75° F. is reached the pentane starts to condense, out of the vapor, and continues to condense out, at 75° F. until the bubble point is reached.

Fractionator Operation

(1) In any commercial tower operating with a finite reflux ratio of overflow to product, how does the composition of the more volatile hydrocarbon in a binary liquid mixture on a tray compare in richness with the same component in the vapor both above and below that tray?

The more volatile component is leaner in the liquid

than it is in either the vapor above or below the tray. The vapor above the tray is richer in that component than the vapor below the tray. This fact can be shown (Figure 2) graphically by reference to a small section of the tower either above or below the feed plate.

(2) In any adiabatic fractionator operating at 100 percent efficiency with total reflux or an infinite ratio of overflow (or reflux) to product, how does the more volatile hydrocarbon in the liquid on a tray compare with the vapor above and below the tray?

The vapor above is richer in the more volatile component than the liquid.

The vapor below has the same composition as the liquid on the tray into which the vapor is rising. (Figure 3.)

Although one rarely thinks of a bubble-plate tower as a heat exchanger, it is nevertheless, in a way, such a piece of apparatus. The upward flowing vapor stream is carrying latent heat towards the top of the tower and the reflux is picking up sensible heat as it flows downward. The efficiency of a bubble plate has been measured by Carey[1] in terms of this heat exchange. Figure 4 shows the temperature changes which might be apt to take place in the flow of the vapor through a plate and the liquid across the plate. The resistance to the flow of heat from the vapor into the liquid prevents the complete attainment of a temperature equilibrium in the finite contact between the two phases.

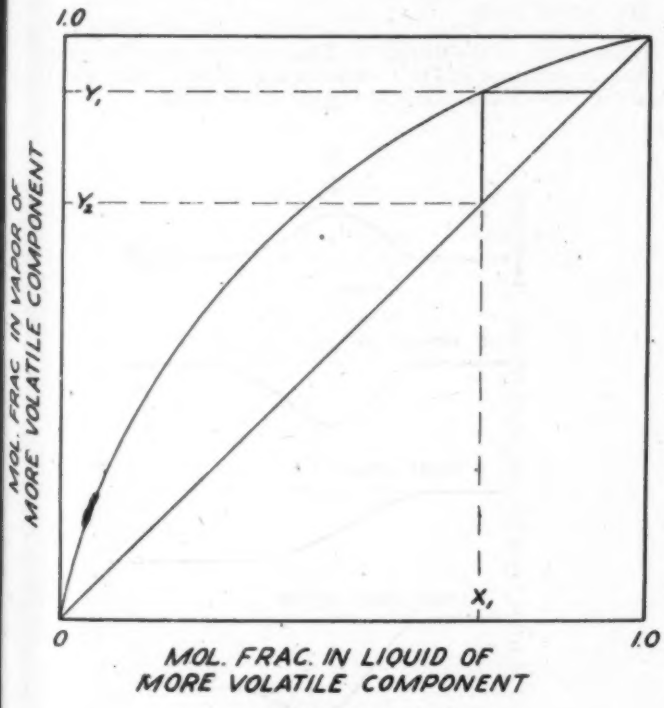


FIGURE 3

Fractionation of a Binary Mixture with total reflux. Vapor and liquid compositions around a plate.

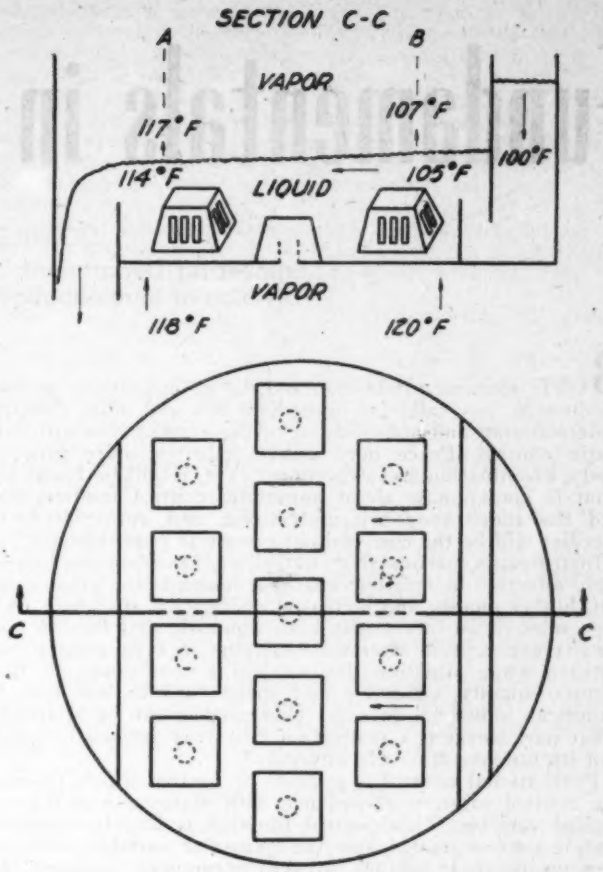


FIGURE 4

The fractionator as a heat exchanger. (Temperature relationships between vapor and liquid.)

In a total reflux tower or one in which equilibrium is attained on each tray, the vapor will emerge at the same temperature as the liquid from which it is rising.

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Fundamentals in Automatic Control

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BOTH wartime production and, by all indications postwar production, too, calls for immediate full and more complete understanding and appreciation of the fundamentals of automatic control. Peace may assure industry more time for study, examination and experiment. Yet, it will be found that what is known now about automatic control fundamentals, and the more they are understood and appreciated, the speedier will be the conversion to postwar requirements.

Instruments, particularly controllers, have become increasingly effective in meeting wartime demands for greater output, higher quality and increased operational efficiency. With a promise of an increase in both domestic and foreign commodity competition after the war, plus an even greater competitive wage situation due to world conditions, all three factors—quality, efficiency and speed—will be the basis for American industrial success. That success can be attained in great part through a realization now that automatic control and its fundamentals are important.

Proportional control is a mode of control which positions the control valve in accordance with magnitude of the controlled variable. This control function is largely stabilizing and, if not too great, forces the controlled variable to line out at some point. It will not prevent permanent deviation from the control point upon a change in load.

Reset response provides an additional increment of valve position in proportion to the deviation and the time of deviation of the controlled variable from the control point. This control function has very little stabilizing effect but, if not too great, tends to prevent deviation from the control point for changes in load.

From these definitions it is obvious that the control system and the process must be considered together as a dynamic unit, since a change in one part carries through so as to affect the whole system. Thus, automatic control must always be measured in terms of moving or dynamic conditions, not steady or static conditions. One proof of this is shown by the fact that a deviation must be detected before the controller can act. Therefore, a deviation, no matter how small, must occur.

In nearly all cases discussed here the controlled variable will be temperature. The discussion applies in general, however, to the control of pressure, flow, and liquid level when allowances are made for the greatly different process characteristics.

Action of Control Responses

Disregarding the process for the moment, we wish to study the pen and valve movements when proportional and reset responses are used in the control system. Figure 1, Curve A, shows a deviation which has been chosen as an example. The control valve is by-passed so that no control action results from its movement.

In the definition of proportional action, valve position was found to be proportional to the deviation. Curve B shows the valve movement that would result from this deviation when a proportional controller is used. Note that this curve is similar to the deviation curve. A proportional controller always has the characteristic that a certain pen position is accompanied by a certain valve position. Stated in other words, the rate of valve movement is always proportional to the rate of pen movement.

In actual practice this recovery action would result from a very temporary change in load, the load returning to exactly its previous value.

In the definition of reset response, the valve position was found to be proportional to deviation and time of deviation. Suppose that, at the time interval marked "dt" on the time axis of Curve A, the deviation in temperature is D as shown. The definition of reset shows that during time dt the valve will move an amount proportional to D times dt.

If we start at the beginning of the deviation and move the valve at each dt an amount proportional to D × dt, the valve will move as in Curve C. What really has happened, is that Curve C represents the area under the deviation curve and the reset has integrated or added the sum of the small D × dt areas.

But since reset response is generally used in conjunction with a proportional controller, these two effects must be added together. Curves B and C are added and shown in Curve D.

In actual practice, this recovery curve would occur on a permanent change in load, reset response having closed the valve an additional amount to maintain the temperature at the control point.

It is easy to show how controller actions bear a definite relationship to the deviation. These actions may be combined into an equation and it is surprising to dicover how well automatic controllers follow a definite relationship.

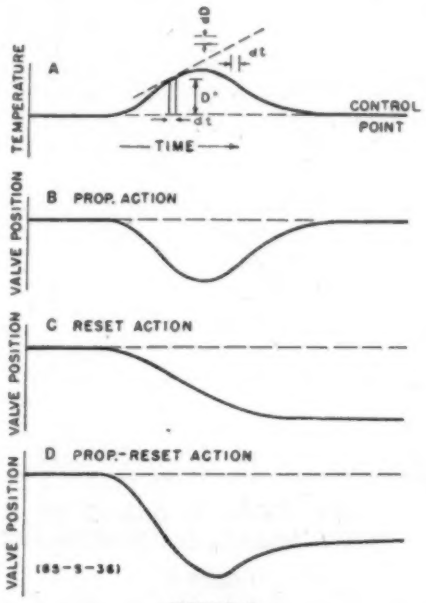

FIGURE 1

First, in reset action, valve position is proportional to the area under the deviation curve. As before, this area was obtained by adding all the deviations multiplied by the time at the deviation. In proportional action, valve position is proportional to the deviation.

We may combine these actions and show the valve position at any time as an equation:

$$V = K_1 \int_{ti}^{ta} D\,dt \;\text{(reset)} + K_2 D \;\text{(proportional)} \qquad (1)$$

V is valve position
K_1 is the reset rate-adjustable constant
D is the deviation of variable from control point
K_2 is the proportional band-adjustable constant
t is time

If a controller does not have all these responses the appro-

priate term is zero. Thus, a proportional controller would be

$$V = K_2 D. \quad (2)$$

Equation (1) is of the type which is known mathematically as the first few terms of an infinite series. Thus it might be possible to add to the controller response many of the higher derivatives as below:

$$V\ K_1 \int_{ti}^{ta} D dt + K_2 D + \frac{K_3 d D}{dt} + \frac{K_4 d\ D}{dt} + \frac{K_5 d\ D}{dt} \ldots \text{and so on.}$$

A controller built to include many higher derivatives, even if electronic in nature, would be far too complicated and expensive. From a practical standpoint, proportional response alone is sufficient to handle significantly large numbers of processes.

Process Characteristics Affecting Control

All processes are more or less complicated arrangements of a number of capacities, transfer lags, and dead times. The extent of these factors determine the complexity of the control problem.

Capacity produces a retardation, not a delay, by the ability

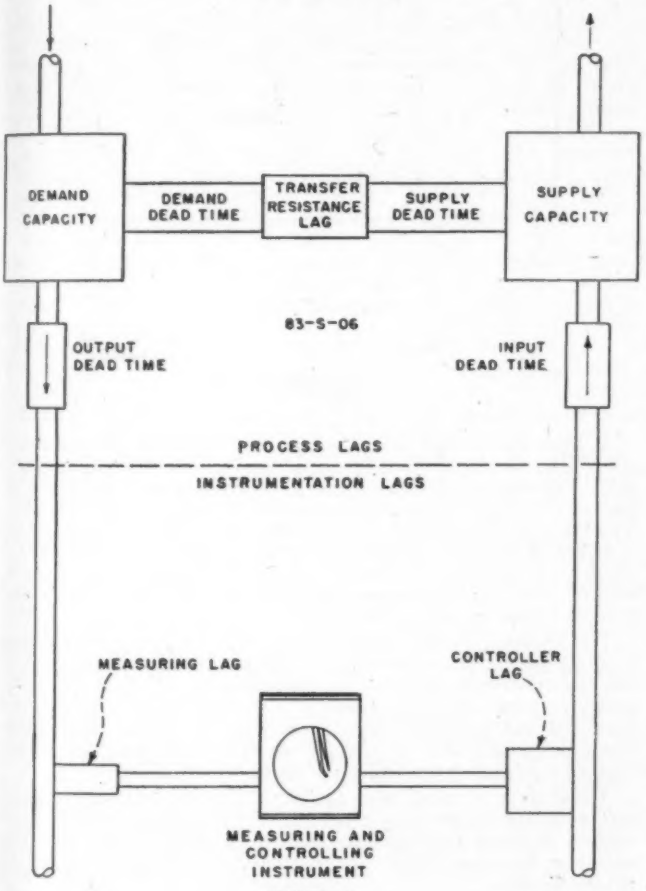

FIGURE 2

of sections of the process to absorb energy without causing an immediate full rise in potential. Compare this with an electric capacitor which can absorb electrical current and thus delay the rise of voltage until it is charged. The ability of the brick walls in a furnace to absorb heat, the volume of liquid in a tank which affects the liquid level, and the amount of steam required to raise the pressure in a steam cooker, represent capacity.

Transfer lag is a retardation, not a delay, caused by the potential drop between two separated capacities or over distributed capacity in the process. This can be compared to an electrical resistor between two electrical capacitors. The temperature drop across a boiler tube or a heat-exchanger tube, the pressure drop across a valve connecting two tanks, or the temperature drop across an insulating wall represent resistance of the kind which causes transfer lag.

Dead time is a pure time delay which arises from the necessity of transporting a mass of liquid, gas, or solid from one point to another. The distance between a heat-exchanger outlet and the thermocouple, and distance between an oil burner and the material being heated, and the distance between a control valve and the fuel burner, all represent a small but sometimes appreciable dead time during which time no change can be effected.

Not only the process itself, but the measuring and control systems have capacity, transfer lag, and dead time. Figure 2 shows a typical process with all the various sections which make up the system. All processes or controllers do not have this arrangement, some having fewer and some having more component parts.

Consider what actual characteristics enter into each of the blocks in a diagram. Assume that the process is a fuel-fired waterheater and that we wish to know what each of the blocks in the diagram represents.

Input dead time is the time required for fuel oil to flow from control valve to burners.

Supply capacity is the heat storage capacity of the firebox.

Supply dead time is the time required for hot gases or flame to travel from firebox to water tubes.

Transfer resistance is the resistance to heat flow across the water tube from gases to water.

Demand dead time is the time required for water to flow from water tube to header.

Demand capacity is the heat storage capacity of water in tubes and header.

Output dead time is the time required for heated water to flow from the tubes or header to the point where the thermocouple or the thermometer bulb is located.

Measuring lag is represented by the heat capacity and resistance to heat flow in the thermocouple or thermometer bulb and its protecting well.

Controller lag is represented by the lag of response of the control valve—in electric control by the speed of the motor valve operator, and in pneumatic control by the pressure storage capacity of the valve topwork.

Process Reactions

In order to illustrate the effect of capacity, transfer lag, and dead time, we may employ the reactions of the furnace or other process to changes in fuel flow. This method was previously used to illustrate controller action by moving the pen and observing the resultant valve action. To illustrate process characteristics we move the control valve and observe the action of furnace temperature.

The reaction curve is simply the curve of temperature (or other variable), versus time that would be drawn by a recording instrument if the control system were disconnected from the instrument and a change made in control-valve position. On pneumatic controllers this may be done by disconnecting the line leading to the valve, and connecting a separate air supply. By varying the valve pressure a known amount, the temperature would rise or drop to a new value.

Figure 3 shows the effect on the reaction curve of three characteristics which greatly influence automatic control: Capacity, transfer lag, and dead time.

The effect of capacity in a process is shown by Curve A. Capacity allows the temperature to change instantly when the control valve is moved but the temperature gradually approaches a final value—a typical logarithmic reaction. This type of process reaction is desirable since it provides instantaneous response of temperature but slows down the response sufficiently to provide stability. A reaction such as shown by Curve A is an ideal which is rarely obtained. When a second capacity is associated with the process a transfer lag is generally caused as shown by Curve B. This transfer lag is illustrated by the slow initial response to valve movement which gradually builds up to a maximum rate of reaction. Note that this reaction is greatly different than when only a single capacity is involved as in Curve A.

The effect of transfer lag may be caused by any additional retarded response in the process or in the control system. This is a very important consideration in automatic control. The effect of transfer lag arises from:

1. A supply capacity in a process.
2. Distributed capacity in a process.
3. A measuring lag.
4. A controller lag.

Since transfer lag is nearly always detrimental to automatic control all four conditions above must be avoided whenever possible.

By using greater process capacity the effect of transfer lag may sometimes be overcome. Curve C illustrates a much greater process capacity than Curves B or A. Transfer lag is indicated by the slow initial rate of change of temperature.

Dead time is the cause of much difficulty in automatic control. When dead time exists, as shown in Curve D, a control valve movement cannot be made effective until the dead-time

period has passed. Therefore, any deviation which occurs during the dead-time period cannot be avoided.

In automatic control, it is usually outside disturbances or load changes which cause the major difficulty, and not control of the variable itself. Then, also, the lags of the measuring and controlling systems of the controller form a

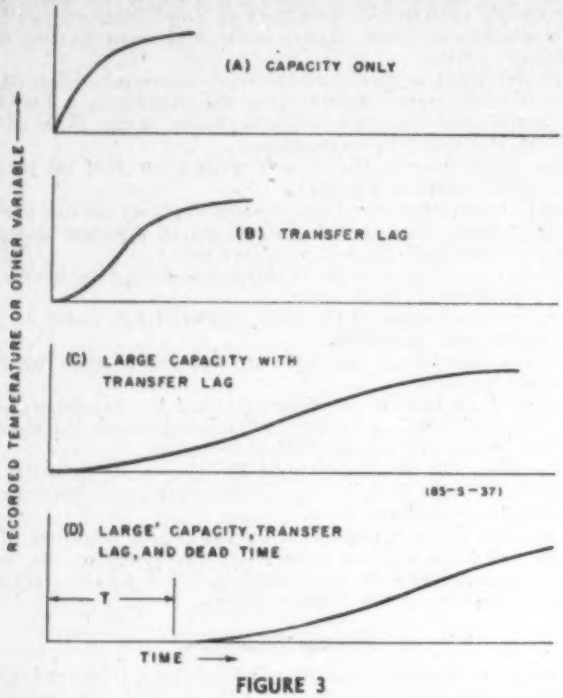

FIGURE 3

very important part of an automatic-control application, especially when process transfer lag and dead time are small.

Practical Aspects of Control

There are several factors entering into the control of various processes which produce relatively great improvements in the quality of control. They might be called "fundamentals" but this is only to emphasize their importance.

Any reduction of the dead zone of the measuring system causes improvement in the quality of control, especially for processes having large capacity and transfer lag.

To show how this comes about a reaction curve for a process having capacity, transfer lag, resistance, and dead time, has been redrawn to a larger scale and only the deviation from the control point is shown in Figure 4.

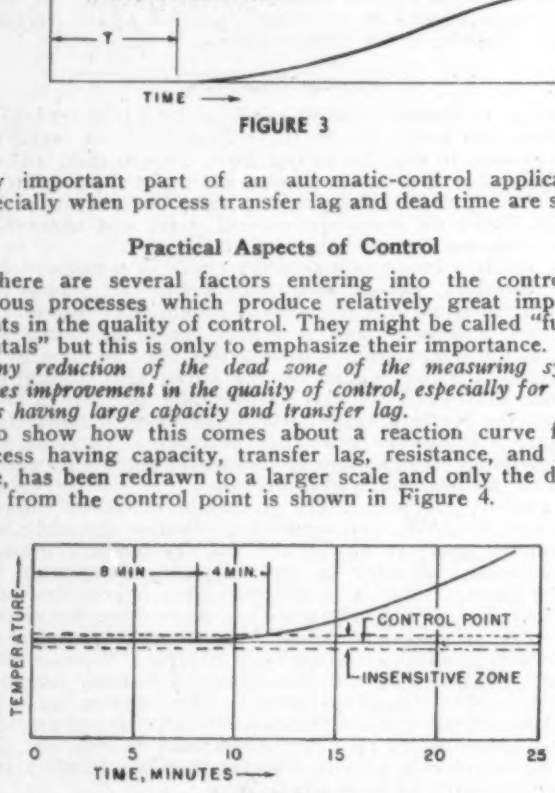

FIGURE 4

This is the beginning of deviation from the control point and, from the time that the deviation started at eight minutes until the deviation is several percent of the controller scale, the control system should begin to function. However, in most measuring systems there is a small zone through which recording is insensitive, that is, the variable (temperature in this case) has changed but the controller fails to detect this change. This dead zone has variously been called "dead spot," "tapping error," and "neutral zone."

Dead zone usually is attributed to the measuring system but may also exist in the control system. Pneumatic controllers are sufficiently sensitive so that as soon as the pen or pointer begins to move, the control system begins to function.

In Figure 4, the dotted lines above and below the control point represent the width of the dead zone. In this case, the control system does not function until the temperature exceeds the dead zone and it is necessary to wait for four minutes before corrective action is made. These four minutes are in addition to the dead time already existing in the process and control system.

Since it has already been indicated that dead time is the cause of one of the most serious difficulties in control, a dead time in the controller further complicates the problem.

An improperly located or poorly installed measuring element results in poor control as well as poor accuracy of measurement.

Much has been said and written concerning the effect of poor thermocouple or thermometer-bulb installations on the accuracy of temperature measurement. Its effect on automatic control, however, is not so immediately obvious.

Suppose, for example, that a thermocouple installation as shown in Figure 5 were encountered. A large loss of heat will occur along the protecting well and heat will be lost to the atmosphere because of the long length of protecting well outside the pipe. This loss decreases the heat available at the thermocouple tip and the temperature reaction at the controller is slow.

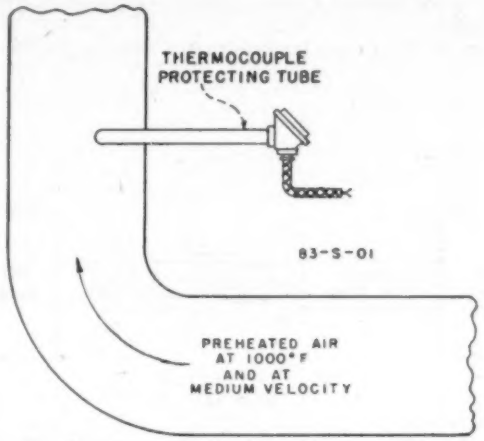

FIGURE 5

A protecting well installed in a horizontal position will allow dirt to settle on the tube if the velocity of the gas will not scour the surface. This increases the thermal capacity because the additional mass must react to temperature changes. The resistance to heat flow from the air to the protecting well is fairly high because the thermocouple tip is located near the outside of the pipe where the velocity is even less than in the center. This increases the measuring lag so that the temperature response is even slower.

The location of the thermocouple downstream from a bend in the pipe causes unnecessary fluctuations of temperature at the thermocouple because of the swirling effect of the gases going around the bend. Usually a thermocouple and protecting well has enough mass to smooth out those fluctuations but comparable difficulties are often encountered in a flowmeter or pressure control installation.

These general principles apply to the installation of almost any primary measuring element. Very careful consideration should be given to the losses and to the mass of the detecting element because they very greatly increase the lag of masurement.

Make sure that the control valve is properly installed and is of a type best suited to the job.

In addition to the choice of lift-flow characteristic for a control valve, it is most imperative that it be smoothly operating, that is, have smooth increases in flow for increases in lift or rotation.

On pneumatic control valves this involves maintaining adequate lubrication of the stem and repacking at frequent intervals when necessary. The average pneumatic control valve, when properly maintained, will operate very satisfactorily but friction at the valve stem which causes sticking can very seriously reduce the number of positions available at the valve. For this reason, there should be no hesitation in using a valve positioner, even if the sticking is only moderate. A valve positioner should always be used, of course, when the proportional band is set to wide values.

Electric-motor-operated valves should not be operated with the shaft vertical because thrust causes excessive wear. It is most important that the motor oiling instructions be carefully followed. The resistor and operating contact, as well as the limit switches, for electric control systems should be in-

■ CONTINUED ON PAGE 120 [76]

Fatty Acids by Oxidation of Hydrocarbons

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IT IS desirable to report the more recent developments in the oxidation of oils to fatty acids since I gave my review paper on the manufacture of synthetic fatty acids[1] in 1933. Developments before then are covered in that paper. Since that time rapid strides have been made in oxidation procedures, especially the technically developed processes to increase yields, improve the quality of products, etc., in Germany but even more extensively in Russia and the United States.

The processes for producing fatty acids had been perfected fairly well on the Continent but the economics of the whole operation were such that development lagged, due to a lack of the raw stocks suitable for oxidation, and where available such stocks were too costly to convert to acids which had to compete with low-priced fats from the stockyards industries; operating costs were also high.

Considering a typical case, for instance, in Germany where 1.7 million tons of fats are consumed per year on an average, and that 375,000 tons alone are consumed by industry (importing 60 of the above in the form of raw fats[2]), then the question of synthetic-fat production looms large and becomes important from many angles. Every ton of synthetic fatty acids frees a corresponding ton of fat for human nutrition and represents a saving in national costs.

In Russia where petroleum and paraffinic materials are plentiful, large installations have been erected, especially in Kazan and in Gorki, for manufacturing fatty acids from vaseline-oils, spindle-oils, Grossny paraffins and other petroleum products.[3] In the United States, where again petroleum production is very high, the development has been mainly along the lines of improving yields and efficiency of the processes themselves.

In America and in Europe the developments have been not only in the technique of oxidation itself but even more so in the field of preliminary treatment of the hydrocarbon material and rational procedure for working up the finished product. The following descriptions of processes and patents are from recent literature and petroleum technologists are urged to investigate these processes further so that future development in this field can be further enlarged and improved.

Pretreatment of Hydrocarbons

Sulphur, nitrogen and oxygenated compounds invariably comprise the impurities or contaminants of most hydrocarbon oils as first obtained in petroleum distillation operations. These groups exert a disturbing effect on the oxidation. N. J. Tschernoshukow and S. Krein studied the oxidation reaction and sought to clear up the question of the effect of impurities in the raw material.[4] They had found that aromatic hydrocarbons without alklyl groups, such as naphthalene, anthracene, and phenanthrene did not oxidize or were very difficult to convert to acidic material. These actually stabilize hydrocarbons. Compounds with carbon chains between the rings in contrast to the above lower the oxidation stability and lead to the formation of resins of acidic character. Furthermore, with increased length of side chains the formation of acid-oxidation products overbalances that of resin formations, which latter are true condensation products.

According to these authors' investigations paraffins from Grossny yielded the greatest amount of condensation products and only a small quantity of acid products; whereas the solar oils from Baku furnished small amounts of resins and a high percentage of acid products. Aromatic hydrocarbons without side chains decrease the rate of oxidation of paraffinic or vaseline type of oils, even though the former actually take part in the oxidation reaction.

Materials which seem to influence the formation of oxygenated compounds appear to be, according to the above authors, the phenols, quinone, and similar derivatives, increasing the stability of vaseline or paraffinic oils, while aldehydes, ketones, fatty acids and oxy acids decrease the stability of paraffinic materials. Pyridine bases lower the stability and increase the yield of tars and sludges. Sulphur compounds appear to be anti-oxidants.

In order to remove, before the oxidation process, the above type of compounds which have the adverse effect for the oxidation reaction there appear to be two procedures, according to the I. G. Company, which are recommended for removing impurities and the like. According to the older patent[5] one treats the raw hydrocarbon with concentrated sulphuric acid in the presence of small amounts of inorganic nitrogen-oxygen type of compounds, such as nitric acid, nitrous acid, nitrogen di-oxide, or nitrosyl sulphuric acid, at a sufficiently low temperature to avoid any attack on the hydrocarbon itself. For instance, commercial hard paraffin of 320° C. melting point is treated with 4 percent concentrated sulphuric acid containing 0.2 percent nitric acid for 15 minutes at 80° C., followed by removal of the acid and water-washing. After blowing this treated paraffin with air at 160° C. (using ½ cubic meter air per hour per kilogram of wax) there is obtained a product containing 50 percent fatty acids, whereas by blowing the untreated wax one obtains only 35 percent of wax acids.

In a later patent by the I. G. Company[6] there is revealed a procedure to destroy the anti-oxidants in raw oils by treating the raw stock with anhydrous halides, such as boron fluoride, boron chloride, silicon chloride, aluminum chloride, and the chlorides of iron and zinc. These chemicals are used in amounts of about 1 percent at a temperature of 50°-110° C. These reagents are selected inasmuch as they very easily hydrolize in water. Anti-oxidants and other disturbing impurities form polymerization products with the above reagents, and these products are drawn off from the treated oils as a viscous lower layer. The top layer, which is the purified or treated oil, after careful separation is given a filtration with bleaching clay, silica gel or activated carbon. Oils treated in that manner yield, upon oxidation, only very small quantities of overoxidized by-products in contrast to the untreated oils. One also obtains purer fatty acids and in much better yield.

For instance, brown crude paraffin-wax, derived from the hydrogenation of lignite, is treated with aluminum chloride as described above; this is followed by oxidation, using 0.3 percent of manganese sterate and 0.2 percent of alkali as oxidation catalysts; one obtains a very excellent crude oxidation mass which, after further separation of unsaponifiable matter, yields pale fatty acids containing less than 0.5 percent of oxy-acids insoluble in petroleum ether.

Standard Oil Development Company prefers to hydrogenate the raw paraffinic oil which, upon oxidation, furnishes only pure fatty acids without any resinous by-products. For example, the oils are treated with hydrogen under pressure. Hydrogenation catalysts are preferably used and they are mixtures of the oxides of chromium, tungsten, or other metals of the seventh group together with magnesium or

zinc oxide. This process is carried out at 250°-350° C. at a pressure of about 200 atm. The product is then ready for oxidation and is blown with air at a relatively low temperature of about 150°-170° C. The yield of fatty acids is between 50°-70° percent[7].

The Russian investigators Petrow, Danilowitsch, and Rabinowitsch[8] subject crude distillates, such as solar, spindle, machine oils, and the like to a sulphonation procedure obtaining in this manner sulphonated products, designated as "Petrow-splitters," which are used in the splitting of fats. The purified or unsulphonated portion is then used in the oxidation process.

Improvements in Oxidation Processes

The most recent work undertaken by the I. G. Company consisted of research for finding more efficient catalysts for the oxidation. These catalysts have been grouped into three series of chemical substances. The catalysts used in the past were oxygen-containing combinations or organic salts of zinc, manganese, nickel, and cobalt. Powerful as they were in the general reaction, their use resulted in discoloration and in the formation of resins which are found in the final product. Fatty acids separated from this final product are then strongly off color and nearly always contain appreciable amounts of oxy-acids. In attempts to hinder this over-oxidation during the reaction (which could be accomplished by converting the acids at once during oxidation to soaps with alkali) there would then result a slowing up of the over-all rate of oxidation, no matter how efficient the apparatus or how well one distributed the air entering the mixture to be oxidized. Products obtained by this procedure were not satisfactory.

Very good-colored fatty acids, however, are obtained in good yield and in very short time by conducting the oxidation in the presence of small amounts of oxygen-containing organic derivatives of the alkali-earth metals, or those of magnesium or aluminum. These catalysts actually dissolve in the hydrocarbon to be oxidized or finally in the oxidation product itself; it is not necessary that free alkali be present at any time. For this purpose one employs the stearates, oleates, or cinnamates of the above-mentioned metals, as well as the alcoholates or their phenolates.

The oxidation is conducted at 130°-150° C. in tall vessels filled with baffle-plates or packing material. Very small amounts of these catalysts are necessary, such as 0.1 percent barium stearate, in order to obtain good yields, high reaction rates, and light-colored acids. Acids obtained in this manner contain only negligible amounts of by-products insoluble in petroleum ether. Oxidizing a low-melting-point wax in this manner yields a light-yellow, soft product showing a saponification number of 236.[9]

In a later patent by the I. G. Company there is disclosed the use of catalytic metals in the form of organic enolate derivatives, such as aceto-acetic esters, acetylacetone, benzoyl-acetone, and the like; these derivatives are true enolates. Again these derivatives have the desired property to disperse and also actually dissolve in the hydrocarbon. They do not direct the oxidation toward formation of resins as do the metallic naphthenates. Resinous materials formed under the old procedure contain metallic compounds which sludge on the surface of the packing in the oxidizer.

If one also precipitates metallic salts in the presence of such enolate derivatives there are obtained mixtures of metallic oxides and metallic enolates which can be used directly as oxidation catalysts. As opposed to the alcoholates which decompose in moist air and water, the enolates are not affected by moisture or by the water formed in the oxidation reaction, and they therefore do not lose any of their acidity. One of the most efficient catalysts of this type, for example, is manganese acetylacetonate, which is used in amounts of 1 percent.[10]

Other catalysts, of course, can also be used to advantage under certain conditions. Combinations of this type consist of oleates, naphthenates, palmitates, resinates, etc., on the one hand, and derivatives of alkalis or the alkali metals, including even magnesium and compounds consisting of the heavy metal series. The above mixtures also can be used as aluminum derivatives in combination with alkalis or heavy metal salts. This list can be extended to include combinations containing oxides, hydroxides, carbonates, carbonyls, or carbides which serve as starting materials for other catalytic combinations. These are catalysts that will actively aid in rapid oxidation of solid paraffin, ceresin, gasoil, lubricants, and also naphthene hydrocarbons.

With the use of this type of catalyst oxidation proceeds rapidly and a good yield of light-colored acids is obtained. As an example, a Pennsylvania gasoil or light neutral is oxidized using 0.4 percent of sodium palmitate and 0.6 percent of aluminum palmitate at 160° C. by blowing with air for eight hours. The quantity of air used is one cubic meter per kilogram of oil per hour. The oxidized product shows a saponification value of 149.[11]

According to a very recent patent of the I. G. Company the optimum conditions for obtaining fatty acids with only a minimum content of petroleum ether insoluble matter are as follows:

1. Controlling the temperature definitely between a range of 90°-120° C.; not over 125° C.
2. The use of a mixture of a manganese compound and an alkali—for instance, manganese stearate with small amounts of caustic soda.
3. The oxidizing gas must be very finely sprayed or distributed into the oil or wax entering the apparatus at the bottom, preferably through a porous dispersion plate or unit.

Keeping within the above requirements there can be obtained a high-grade reaction product which is distillable and will then yield water-white fatty-acids containing only ½ percent of oxy-acids. These fatty acids are very easily worked up to high grade soaps.[12]

Acording to very recent contributions, catalysts of the above type can actually be dispensed with since it has been discovered that the nor-acid and unsaponifiable (ketone material) separated from previous batches of reaction products are really good oxidation catalysts when used in rather large quantities, such as 25-50 percent. This material is added to the oil or wax to be oxidized and it has been found that these ketone materials are good catalysts.

According to the practice carried out by Alox Corporation the oxidation can be carried out in this manner at much lower temperatures than with foreign catalysts and one can operate at pressures from 7-25 atmospheres, which results in very high yield. The foreign or metallic catalysts previously described invariably settle out on the walls and at the bottom of the oxidizer, resulting in poor catalytic activity. Ketone material just mentioned, which is obtained from a previous oxidation is of such nature that it remains practically in complete solution in the oil and is a very active catalyst.

The whole procedure has the advantage of very low cost and is simple to carry out. The oxidation can in many cases be driven practically to completion so that only 1 percent of the original stock remains unoxidized. The fatty acids are extracted from the crude reaction-material with medium-boiling petroleum distillate; using Pennsylvania crude oil, 100-110 percent solid or semi-solid fatty acids have been obtained by this procedure.[13]

The refineries which are in Russia, and operating the oxidation processes, use in the main the procedure of Petrow, Danilowitsch, and Rabinowitsch. After the sulphonated material is drawn off from the unsulphonated oil, the latter is water-washed once and then dried. It is then blown 48 hours with air at 98°-115° C.; using 0.12 percent of calcium naphthenate. The crude reaction mass is converted to soap using 20-25 percent alkali. Blowing for 48 hours results in a yield of about 20 percent of fatty acids. The ratio of the carboxyl acids to oxy-acids is about three to one. The unoxidized oil is again used in the next oxidation, and if preferable, again in a third step for oxidizing with fresh added material. This process can be repeated so that all unoxidized oil is eventually converted.[14] The use of calcium naphthenate seems preferable to using manganese salts since the former gives a higher yield and quality of true fatty acids with less oxy-acids.

The disadvantage of the Petrow procedure is the rather large amount of air that is called for. These investigators claim the use of 12,000 cubic meters of air per ton of fatty-acids produced and that only 5 percent of this quantity actually enters into the reaction. The tendency in Russia therefore has been to investigate oxidation procedures wherein only a small amount of the above stated air is necessary. G. Juchnowskij and S. Rochlin oxidize vaseline oils at a pressure of 3-4 atmospheres at 112°-114° C. and after 8 hours they obtained 20 percent fatty-acids, containing 75 percent true fatty acids and 25 percent oxy-acids. This procedure has another advantage in that even poorly refined oils can be converted.[15]

Over-oxidation is usually the result when blowing is continued for too long a time. In order to minimize over-oxidation Danilowitsch and Dianina have developed a stepwise oxidation process which seems to give very good results. For instance, they have blown vaseline oils with air for 24 hours at 85°-90° C., followed by saponifying the fatty acids with strong alkali and separation of the unoxidized portion.

The unoxidized material is now oxidized again in two steps for a period of 12 hours each, proceeding as above. About 10 percent of fatty acids are formed in each step-wise oxidation. A total of 30 percent fatty acids and about 13-15 percent of oxy-acids are obtained by this process. Other procedures usually give a reaction product containing about 31 percent of oxy-acids, such as are obtained by the unimproved procedure mentioned above. In the step-wise process one also obtains much purer and better colored acids, and it should be remarked that the cost of the apparatus in the latter case is low and the setup is quite simple.[16]

According to the Petrow patent[17] the oxidation is carried forward so as to secure about 20 percent of acid material. The reaction product then is neutralized with caustic soda, and the material is further oxidized without any removal of the soaps. I. Sherweda and E. Kogan describe a procedure for the oxidation of ceresine. It is known that ceresine oxidizes much easier than does paraffin and the oxidation forms a much greater quantity of true fatty acids with considerable lower content of oxy-acids; 4-8 percent of the latter with a total of 38 percent of fatty acids. The ceresine is blown 6 hours with air at 160°-170° C.[18]

Besides using air as the reagent for oxidation there are also procedures in which nitric acid or nitrogen oxide derivatives are used as the oxidants. According to the investigations of Schwedowa, Kresin, and Andrejewa, natural waxes and saprolites are oxidized with 37 percent nitric acid, yielding products which are considerably richer in petroleum-ether-soluble portions and which have the characteristic of giving foaming solutions when the oxidized material is treated with alkali. The soaps can be salted out and they have the properties of "true soaps."[19]

Nitrogen compounds containing oxygen (NO_2, N_2O_3) are used by Byrnes for oxidizing heavy Pennsylvania kerosines in the vapor phase. The hydrocarbon is first atomized into a fine mist with air and then brought into reaction with the nitrogen compounds which can be prepared by the decomposition of nitric acid. The oxygen is released from these oxides of nitrogen, reacts and becomes attached to the hydrocarbon. The remnants of the nitrogen derivatives are again converted into higher forms of oxides by the presence of oxygen in the higher forms of oxides by the presence of oxygen in the oxidizing chamber. This procedure is said to have the advantage that oxidations can be carried out at quite low temperatures.[20]

Recovery of Final Fatty Acids

If one saponifies the crude reaction material directly, dark colored soaps are invariably formed which have a disagreeable odor. The I. G. Company has therefore taken out patents to circumvent these disadvantages. The reaction-product is treated with a water-immiscible solvent, such as benzol, benzene, carbon tetrachloride, etc., and then further treated with a water solution of some alkaline reagent, alkali hydroxides, or carbonates, ammonia, or amines. The soap solutions which are thus obtained are next extracted with a water-immiscible liquid in order to remove the remaining unsaponifiable portions.

Upon evaporation and drying of these soap solutions, a good yield of colorless and odorless soap powder which shows good wetting, foaming, and detergent properties, is obtained.[21]

The oxidation products also can be further refined by treating them with some agent splitting off hydrogen, such as by the action of some alkali on a metal under pressure. Acids obtained in this manner show a great improvement in the acid and saponification number over the untreated products and also a much lower content of oxy-acids. For example, a hard paraffin-wax was blown at 150° C. using 1 percent of manganese catalyst. The reaction-product is saponified with a 20 percent water solution of caustic alkali, using 5 percent in excess, and is next purified (soap solution) by treating 4 to 6 hours in a stirring or rotating autoclave by heating to 300° C. in the presence of 0.5 percent of zinc dust. After the removal of unsaponifiable matter with benzene, very valuable fatty acids are obtained by acidifying the alkaline liquid with dilute acid.[22]

The investigators Warlamow, Ojatjew, and Dawydowa have also done considerable work on the removal of oxy-acids from the crude reaction material (obtained in blowing vaseline oils) by treatment of the product with hydrogen-gas. According to their procedure the reaction product is saponified and the soaps brought to a concentration of 15 percent in water solution are placed in an autoclave together with 10 percent excess of caustic potash. The autoclave is then charged with hydrogen gas, sealed, and then heated to a temperature of 290° C.

As an example, the crude reaction-product before this treatment had the following constants:

Acid No.	147
Fatty acids, percent	47.5
Oxy-acids, percent	36

The material *after* treatment with hydrogen shows:

Acid No.	218
Fatty acids, percent	64
Oxy-acids, percent	12

The content of unsaponifiable matter, however, is increased from 16 to 24 percent.[23] The investigators Lichuschin, Massumjan, and Lewkopulo oxidize wide fractions of Russian solar oil, white oil, and fuel residues, followed by saponification with caustic alkali using 25 percent in excess. The soapy emulsion thus formed is next diluted with a volume of 75 percent water in order to remove the main portions of unreacted mineral oil. The watery soap solution is extracted with light petroleum distillates in order to remove entrained unsaponified oil. The fatty acids, soluble in benzine, show an acid number of 153, a saponification number of 200, and an iodine number of 9.3. These fatty acids can be used in the manufacture of soaps to the extent of using 30 percent in admixture with the fats used in the soap industry.[24]

Warlamow and Konigsberg separate oxy-acids from the true fatty acids, using light naphtha, followed by treatment of this benzine solution with sulphuric acid and bleaching clay. They employ four parts of light naphtha for every one part of fatty acids; 6.5 percent sulphuric acid of approximately 95 percent strength is used based on the naphtha solution. After acid treatment the total solution is treated with 5 percent clay.[25]

C. P. Byrnes uses a procedure employing liquid sulphur dioxide for the separation of fatty acids. Temperatures employed for this purpose are usually —18° C. since liquid sulphur dioxide itself boils at —8° C. Liquid sulphur dioxide is used in amounts of about 1-1½ volumes of the oxidation product. The fatty acids and all other acidic material dissolves in liquid SO_2 but practically very little olefinic and aromatic hydrocarbons. This reagent extracts material from the crude reaction product most readily in the following order: acids, aldehydes, and alcohols. By careful procedure and control of the temperature one can obtain a true fractional extraction.[26]

A procedure which has certain good advantages, especially for large-scale operations, is one described by the Colgate-Palmolive Company. The crude reaction material is saponified with an excess of alkali in the absence of water and air. The crude oxidation product is mixed with the dry alkali and heated to 350° C. in the presence of inert gases, such as carbon dioxide, superheated steam, toluol vapor and the like. The gases and products are passed in a current of these inert materials in a continuous manner. Three distinct processes or reactions occur in this procedure: the saponification, a chemical rearrangement of the saponification products, and a purification step. According to the patent description the soaps of the oxy-acids are converted to unsaturated fatty acids, while an alcoholic OH group, together with a hydrogen atom attached to the adjacent carbon atom, gives rise to water formation. The result is that a double bond is introduced between the two carbon atoms. No appreciable decomposition takes place in the strongly alkaline medium and therefore no appreciable formation of gases which would tend to lower the yield. At the temperature stated, impurities are blown out or removed by the continuous stream of inert gases, or superheated steam, which is used in the process. The fatty acids obtained by acidifying the alkaline reaction product are next subjected to a steam distillation. By this procedure fatty acids are obtained in very pure form, almost white in color, free from odor, and with good foaming properties.[27]

Preparation of Sulphonated Products from Oxidized Material

The I. G. Company has obtained material which is water-soluble and which shows all the properties of Turkey-red oil, and their product can be used in place of this oil. This new type of material is obtained by sulphonating with sulphuric acid the partially oxidized material derived from high-molecular-weight fluid or solid hydrocarbons. The sulpho-products after careful neutralization with alkali show excellent wetting, emulsifying and detergent properties. Products of this type are obtained, for instance, by the following procedure:

Hard paraffin wax is oxidized with air for 2 hours at 160°-170° C. The crude reaction product is extracted with methyl alcohol, obtaining an extraction product (free of

alcohol) which shows a saponification number of over 200. This material is reacted by stirring for 2 hours at 35° C. with one third its weight of 98 percent sulphuric acid. The excess of acid is washed out with a solution of sodium sulphate. The washed material is next carefully brought to an alkaline reaction. This product can be mixed with petroleum oils to obtain a high grade cutting or grinding compound when mixed with water to form an emulsion.[28]

It has been shown that for this purpose one can also employ products which have undergone a far-reaching oxidation. Even though such over-oxidized material contains considerable polymerization and condensation products, resins, and the like, these groups nevertheless undergo the sulphonation reaction quite readily.

It is not necessary first to remove the unoxidized portions from the crude reaction material. For example, such a product is obtained in the oxidation of hard wax blowing for 8 hours at 170° C. and using 0.1 percent barium cinnamate as a catalyst. The crude reaction product containing 18.5 percent of unsaponifiable material is dissolved in carbon tetrachloride and sulphuric anhydride is passed into this solution at 30° C. The sulphonation must be carried to completion so that the final product does not contain any of the crude oxidized material.[29] Other sulphonating agents may be used instead of the sulphuric acid mentioned above and in this connection 30 percent oleum is often employed.[30]

Summary

We have shown with the above examples that there is no doubt that any of these processes easily lend themselves to commercial operation for the production of synthetic fatty acids derived from liquid or solid hydrocarbon material. This is especially important since the synthetic produtcs show all the properties and even surpass the natural fats which are valuable in all types of industry.

Synthetic fatty-acid production will tend to become an important industry. There is a parallel of comparison here with the direct manufacture of fuels of all sorts derived from coal. In other words, taking coal as our raw material or the above hydrocarbons as the starting material, we can, for example, in both cases produce from these raw materials new synthetic fuels in the one case, and fatty acids, alcohols, and new derivatives in the case of the hydrocarbons—both series of products having new and novel properties and finding new uses in expanding industries, while the raw materials furnishing these products have themselves somewhat limited application in general. The future of the synthetic fatty acids is very great and will become one of the chemical industries based on petroleum chemistry.

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spected frequently because dirty or corroded contacts can appreciably reduce the number of steps available.

The ambient temperature at an electrically-operated valve should never exceed that specified for that type of electrical equipment. The valve and motor should be installed with the recommended linkage arrangement so that the partial characterization obtained by such means is the most favorable, especially in the case of fuel-air ratio valves.

The influence of outside variables often produces such large upsets that a single controller will fail to maintain process balance. Outside variables should be corrected at the source.

An upset in the supply of the process must carry through the process and finally reach the controller before any correction can be made. The time elapsing between the upset and a complete correction is often very long and serious deviation of temperature may result.

If a controller is applied so as to measure a variable associated with the upset and its effect corrected before it can reach the process, the job of the main controller is greatly reduced and better control will result.

The case in point is the control of temperature of a gas-fired furnace. Pressure changes of a very rapid nature often exist in fuel-gas lines. When using a controller directly operating a valve these pressure changes cause a change in flow of the fuel which, in turn, upsets the control of temperature. The controller then has a difficult time trying to hold the temperature within limits.

Suppose a flow controller is installed in the gas line and the temperature controller is used to adjust the control point of the flow controller. This arrangement is commonly called metered control. Now, if a pressure change in the gas line occurs, the flow controller detects the change in flow and makes a correction immediately without allowing the change to upset the temperature. The temperature controller has a much simpler job to perform and the quality of control is improved.

When possible, therefore, upsets of this nature should be corrected at the source by adding a controller at the proper point. The additional controller need not be a recording controller. Sometimes a pressure-balanced valve or a non-indicating controller will serve the purpose. The results will be far better than by adding all sorts of gadgets to the master controller because the master controller cannot detect the upsets until they have already affected the process.

Many times the upsets are in the form of changes in composition of the material being processed or changes in the heating value of a fuel which cannot be readily controlled. It is then even more necessary to correct these upsets at the source.

An example of uncontrolled upsets is found in the following application. Pressure in a steel furnace was controlled with a furnace-pressure controller and a damper. In the morning wide cycling of furnace pressure was observed. Much difficulty was caused until it was discovered that when the sun hit the building in the morning, the operators opened the shutters in the side of the building to cool the furnace room. The varying wind conditions created varying pressure loss conditions and frequent upsets caused the furnace pressure to continually cycle.

Control of final product is desirable. When impossible, more independent variables must be carefully controlled.

In many cases it is impossible, from the practical standpoint, to control the final product. In this case, more of the independent or outside variables must be carefully controlled so that their effect on the final product can be nullified.

For example, in many heat-treating furnaces metal temperatures cannot be directly controlled. However, by controlling furnace temperature, furnace pressure, fuel pressure, and sometimes furnace atmosphere, the metal being treated can be held to fairly close limits.

In processes having extremely large capacity and large dead time, hours will sometimes elapse before a change can be completely detected. There is a limit to the lag through which any controller can maintain effective control.

Summarizing this discussion, there are many more problems in automatic control than just the controller itself. In any control problem the quality of control can be improved more by carefully analyzing the measurement and the process than by needlessly complicating the control system.

Fabrication Costs of Boilers, Tanks and Pressure Vessels As Affected by Plate Widths

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COST of a vessel for refinery service is of minor consideration compared to its meeting the requirements of safety in the service for which it is intended. This would seem to make the subject of this article of interest only to the vessel fabricator. But plant designers cannot altogether overlook cost, and it frequently happens that piping and openings in vessels require consideration in selection of plate sizes.

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BOILERS, pressure vessels and similar structures may be built of plates formed as illustrated in Figures 1 and 2. Figure 1 shows a drum whose length is equal to or greater than its circumference, while Figure 2 shows a vessel whose circumference is equal to or greater than its length. In either type of assembly, where the shorter dimension does not exceed 195 inches (which is approximately the maximum width of steel plate obtainable) a single plate may be employed. In such case, all the fabricating operations are confined to just one plate, generally of width in excess of 100 inches and as such subject to a "width-extra" charge in addition to the base price.

To avoid width-extras, two plates are sometimes used. This practice requires the handling of two plates instead of one, and more than doubles the number of fabricating operations to produce the same shell. To determine whether one-plate or two-plate construction should be employed, the cost of the additional fabricating operations required for the two plates should be compared with the higher initial cost of the one plate due to its width-extra.

Vessels are also constructed as shown in Figures 3 and 4, where the circumference of the vessel is large, and its length is in excess of the greatest width of a single steel plate which can be rolled. In vessels of such construction also, the widths of plates used exert an important influence on fabricating costs to a degree which can be determined by a consideration of the fabrication costs and of the width-extras involved.

In the one-piece crown and side construction of a locomotive firebox, shown in Figure 5, the length of the plate is the girth dimension and the width of the plate develops the length of the firebox. In the three-piece structure, Figure 5, the length of the three plates becomes the length of the firebox. The one-piece type is a simple matter to lay out and roll, whereas the three-piece construction necessitates the handling and forming of three pieces, as well as the welding and the operations incidental thereto.

In addition to the influence of plate width on fabrication costs, there should also be considered its influence on the volume of production and the manpower requirements.

One-Plate and Two-Plate Construction

The number of manhours required to fabricate a vessel can only be reduced by eliminating or reducing fabricating operations in the shop.

Figure 6 is a flow-sheet showing the comparison in the number of fabrication operations for the one-piece and two-piece shells shown in Figure 2. In the two-piece shell the narrow plates are joined together by means of a circumferential seam in the middle of the length of the vessel. The welding of the extra circumferential seam in the two-plate construction is merely one item in fabricating cost. In addition, all other operations are doubled, such as handling, layout, trimming, beveling, heating, crimping the edges, reheating rolling, assembling, cleaning, chipping, grinding and X-raying. Further extra operations required for the two-piece type are resquaring and beveling edges for the round seam and rerounding the two courses and their fit-up.

The two-plate type of construction it will be seen from the flow-sheet in Figure 6, must undergo a total of 53 operations, while fabrication of the one-plate type of vessel involves only 23 operations.

The reduction of more than 50 percent in fabricating operations, by the use of the one-piece construction, results in economies in fabricating cost, in fabricating time, and in

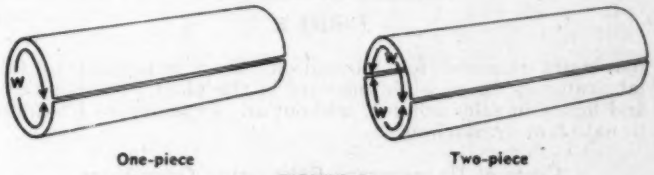


FIGURE 1

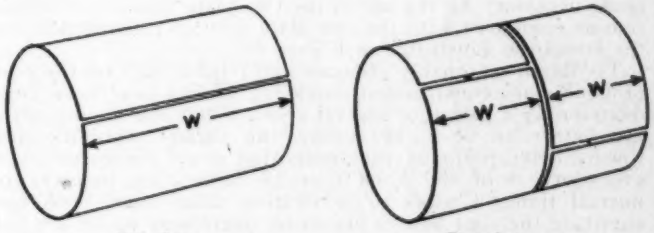


FIGURE 2

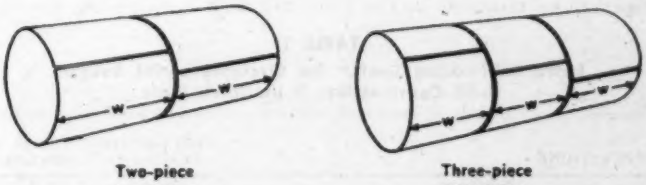


FIGURE 3 FIGURE 4

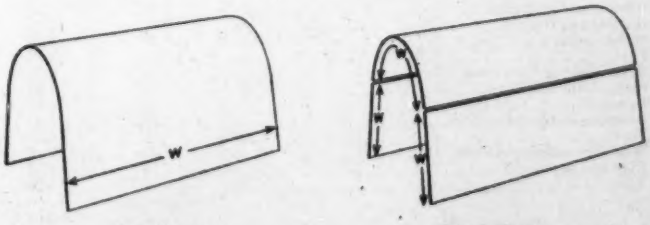


FIGURE 5

FIGURE 6

manhours required for fabrication. Most important to the fabricator is the possible increase in the plant's productivity, and hence in sales volume, without any expenditure for additional plant or machinery.

Costs of Unnecessary Fabricating Operations

What are the costs of the additional fabricating operations made necessary by the use of the two-plate type of construction as compared with the one-plate type of construction for the structures illustrated in Figure 2?

To obtain reasonably accurate and reliable data on the cost of U-68 class construction, intensive studies have been conducted over a period of several years. While fabricating costs are known to be higher today, the studies were directed toward determining average costs that would represent a fair cross-section of the U-68 type of fabricating industry in normal times. Classes of fabrication other than U-68 can eliminate the cost figures herein on operations which are not employed, such as X-raying which is not required on U-69 work, etc.

Table 1 is a typical example of the costs for the extra operations required in the fabrication of a two-plate vessel,

TABLE 1

Extra Fabricating Costs* for Circumferential Seams, U-68 Construction, 2 In. Thick Plate

OPERATIONS	Extra Cost* per Ft. of Seam	Percent Extra Cost
Layout	$ .42	2.21
Trimming	.60	3.14
Machining	.92	4.84
Heating and Crimping	1.50	7.89
Heating and Rolling	2.36	12.41
Shot-blasting	.22	1.16
Fit-Up	.84	4.42
Extra Welding Long Seam	.87	4.58
Clean, Chip and Grind	.29	1.53
Reround	.83	4.37
Resquare and Bevel	1.25	6.58
Fit-up	.83	4.37
Weld Circumferential Seam	5.60	29.46
Chip and Grind	.72	3.78
X-ray	1.76	9.26
	19.01	100.00

* These cost figures include 133 percent shop burden, but not sales or administrative expense or profit. Shop burdens have been found to vary from 100 to 200 percent.

2 inches thick. For comparison with the entire cost of the extra operations, the percentage relationship of each operation is given. It will be noted that the actual welding of the extra circumferential seam—simply one step in the overall fabrication picture—costs $5.60 per foot or only about 29.5 percent of the entire $19.01 which is the cost per foot of seam of the extra fabricating operations required by the two-plate construction. The one-plate vessel, in 2-inch gauge, can effect economy in fabrication cost of about $19.00 per foot of seam, from which saving, the higher initial cost of the one-piece plate, due to the width-extra, must be deducted.

Fabricating Costs and Width-Extras

Width-extras for carbon-steel plates are quoted by the mills in costs per 100 pounds. The fabricator generally estimates his costs per foot of seam per vessel. Hence it is difficult to compare two dissimilar figures and know, for example, the relationship between a width-extra of $0.05 per 100 pounds and a fabricating cost of $11.66 per foot of seam. To overcome this confusion, it is desirable to translate the width-extra per 100 pounds into width-extra per foot of seam or per foot of length of plate.

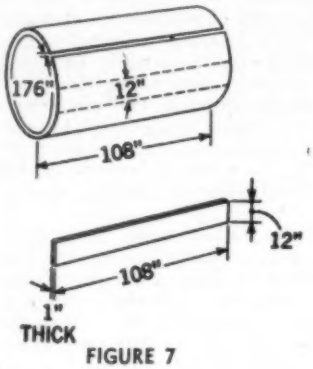


FIGURE 7

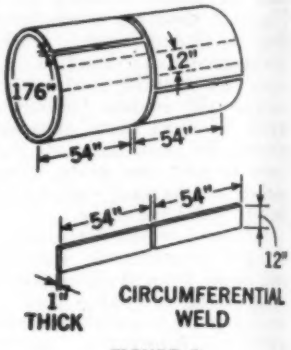


FIGURE 8

Figures 7 and 8 illustrate this common expression in a simple example of a 56-inch-diameter vessel whose circumference is 176 inches with shell length of 108 inches, made from a single plate 1 inch thick, 108 inches wide and 176 inches long. The theoretical weight of this plate, including the maximum overweight allowance of 5 percent, is 385.5 pounds per foot of length of the plate. For the width-extra of $0.05 per 100 pounds for a plate 108 inches wide the width-extra per foot of length of this plate is $0.19. To justify the use of two plates, the fabricator would have to perform all of the extra operations required by the circumferential seam at a cost of $0.19 per linear foot, or less. A good average figure for U-68 fabrication in 1-inch thick steel plate has been found to be $11.66 per linear foot. Thus, using the one-plate shell shown in Figure 7, the fabricator pays $0.19 additional per linear foot of steel plate, but saves himself a fabricating cost of $11.66 per linear foot, for a net economy of $11.47 per linear foot. As the length of the circumferential seam is 14 feet 8 inches, the saving of $11.47 per linear foot becomes $168.22 for the entire shell. The width extra was $1.00 per ton; the net fabricating cost saved by paying it amounts to $59.50 per ton.

Converting to other units, the fabricating cost of $11.66 per foot becomes $3.025 per 100 pounds. By the one-plate construction the fabricator saves the difference between the width-extra of $0.05 per 100 pounds and his additional fabricating cost of $3.025 per 100 pounds, or a saving of $2.975 per 100 pounds, or $59.50 per ton.

As the width of the plate increases, the width-extra per 100 pounds also increases in steps. A comparison of width-extra per foot or per 100 pounds with the fabrication cost per foot or per 100 pounds will determine the optimum plate width.

In Table 2 are given fabrication costs for U-68 construction, per foot, and, per 100 pounds, for circumferential welding and longitudinal welding, and the width-extras per foot, and per 100 pounds, for plate of several gauges and widths.

In the case of the plates of ½-inch gauge in the various widths, it can be seen that the width-extras per foot or per 100 pounds never equal the fabrication cost per foot or per 100 pounds for circumferential welding, and consequently the wide plate is always justified for the fabricating costs given. For example, with ½-inch-thick plate 192 inches wide, the width-extra per foot in circumferential welding is $6.98 compared with a fabricating cost of $8.51 per foot, or on the per

TABLE 2

Fabrication and Width Extra Cost Per Foot and Per 100 Pounds U-68 Construction

Plate Size, Inches	Total Weight, Lb.	CIRCUMFERENTIAL WELDING				LONGITUDINAL WELDING			
		Cost per Foot		Cost per 100 Lb.		Cost per Foot		Cost per 100 Lb.	
		Fabrication	Width Extra	Fabrication	Width Extra	Fabrication	Width Extra	Fabrication	Width Extra
12x108x½	190.9	$ 8.51	$ 0.10	$ 4.46	$ 0.05	$ 6.81	$ 0.10	$ 3.57	$ 0.05
12x120x½	213.2	8.51	0.32	3.99	0.15	6.81	0.32	3.19	0.15
12x132x½	236.7	8.51	1.78	3.60	0.75	6.81	1.78	2.88	0.75
12x144x½	259.5	8.51	2.60	3.28	1.00	6.81	2.60	2.62	1.00
12x160x½	288.2	8.51	3.60	2.95	1.25	6.81	3.60	2.36	1.25
12x174x½	316.5	8.51	4.75	2.69	1.50	6.81	4.75	2.15	1.50
12x192x½	349.2	8.51	6.98	2.44	2.00	6.81	6.98	1.95	2.00
12x108x1	376.4	11.66	0.19	3.10	0.05	9.33	0.19	2.48	0.05
12x120x1	420.2	11.66	0.63	2.77	0.15	9.33	0.63	2.22	0.15
12x132x1	464.5	11.66	3.48	2.51	0.75	9.33	3.48	2.01	0.75
12x144x1	509.2	11.66	5.09	2.29	1.00	9.33	5.09	1.83	1.00
12x160x1	565.7	11.66	7.07	2.06	1.25	9.33	7.07	1.65	1.25
12x174x1	618.2	11.66	9.27	1.89	1.50	9.33	9.27	1.51	1.50
12x192x1	682.2	11.66	13.64	1.71	2.00	9.33	13.64	1.37	2.00
12x108x2	752.8	19.01	0.38	2.53	0.05	15.21	0.38	2.02	0.05
12x120x2	840.5	19.01	1.26	2.26	0.15	15.21	1.26	1.81	0.15
12x132x2	929.0	19.01	6.97	2.05	0.75	15.21	6.97	1.64	0.75
12x144x2	1018.4	19.01	10.18	1.87	1.00	15.21	10.18	1.49	1.00
12x160x2	1131.2	19.01	14.14	1.68	1.25	15.21	14.14	1.34	1.25
12x17 x2	1236.4	19.01	18.55	1.54	1.50	15.21	18.55	1.23	1.50
12x192x2	1364.4	19.01	27.29	1.39	2.00	15.21	27.29	1.12	2.00

100 pounds basis, the width-extra is $2.00 while the fabricating cost is $2.44.

For a 1-inch-thick plate, the width at which width-extras and fabrication costs balance is about 185 inches; for a 2-inch-thick plate, width-extras and fabrication costs balance at about 176 inches.

As Table 2 indicates, the thickness of plate must always be considered in determining the optimum plate width and the calculation for any given gauge cannot be applied directly to other gauges in the same width. While these fabrication costs are acceptable averages for U-68 construction, they will differ for other grades of construction; the fabricator should compute his own fabrication costs for comparison with width extras to determine the optimum plate width in a given gauge, for any grade of construction other than U-68, always being careful to include all items of fabrication costs as shown in the Fabrication Procedure in Figure 6.

Figure 9 shows U-68 fabrication cost per 100 pounds converted from the stated fabrication cost per foot, for two-piece construction and also the width-extras per 100 pounds. The width-extras per 100 pounds charged by the steel-plate industry are shown in the form of steps for widths over 100 inches. Fabrication cost per 100 pounds for the two-piece construction by circumferential welding is shown for certain gauges from ½-inch to 4 inches inclusive.

The use of Figure 9 is illustrated by the following example: a two-piece construction by circumferential welding of a shell 144 inches long and 1 inch thick would require two plates 72 inches wide. As shown in Figure 9 on the 1-inch gauge curve, fabrication costs $2.30 per 100 pounds ($11.66 per foot), while one-piece construction from a plate 144 inches wide would involve a width-extra of $1.00 per 100 pounds. The one-piece construction would save $1.30 per 100 pounds in fabricating cost, or $26.00 per ton of steel plate used in making up the shell.

For a ½-inch-thick shell 132 inches wide constructed from two plates 66 inches wide by circumferential welding, Figure 9 shows that fabrication would cost $3.60 per 100 pounds ($8.51 per foot). One plate 132 inches wide would eliminate the circumferential seam and involve a width-extra cost of $0.75 per 100 pounds and result in a saving of $57.00 per ton in this shell.

The point at which a curve crosses the width-extra line in Figure 9 indicates the plate width for which the width-extra equals fabrication cost. On any curve at any width to the left of the width-extra line, it is more economical to pay the width-extra and use one-piece construction. At any width to the right of the width-extra line, it is cheaper to weld two plates to form the shell or cylinder, provided manpower is available for the extra shop work and production volume is not a major factor.

Figure 9 shows, where ⅝-inch-thick plates or lighter are used, it is always more economical to pay the width-extra and use one-piece construction, while with ¾-inch-, 1-inch-, 3-inch- and 4-inch-thick plates, one-piece construction is more economical in plate widths up to 185 inches and 1½-inch and 2-inch plates up to approximately 180 inches. The location of these points varies with the fabrication cost when grades of construction other than U-68 are used.

While Figure 9 is based on circumferential welding, it is

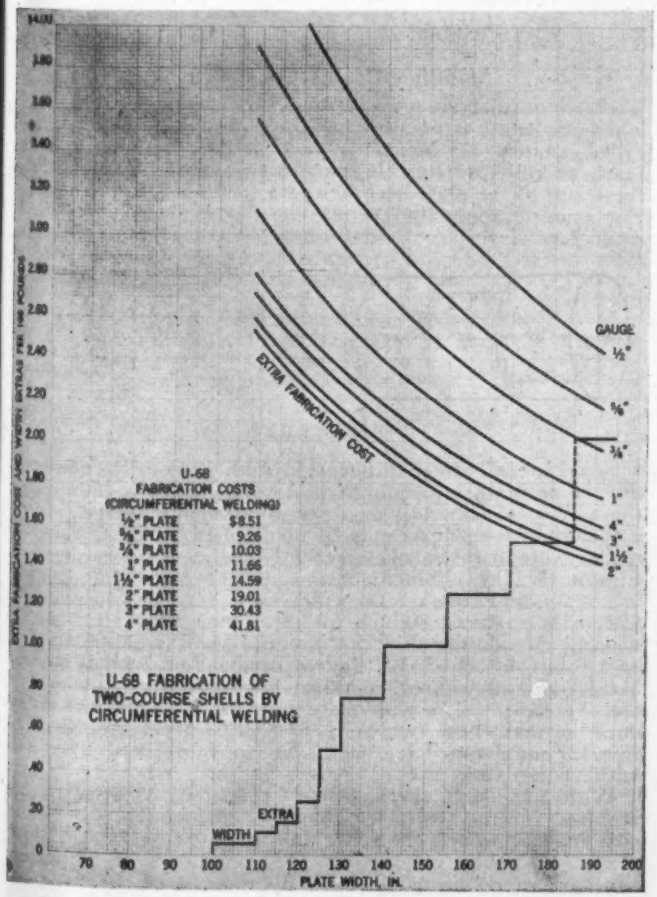


FIGURE 9

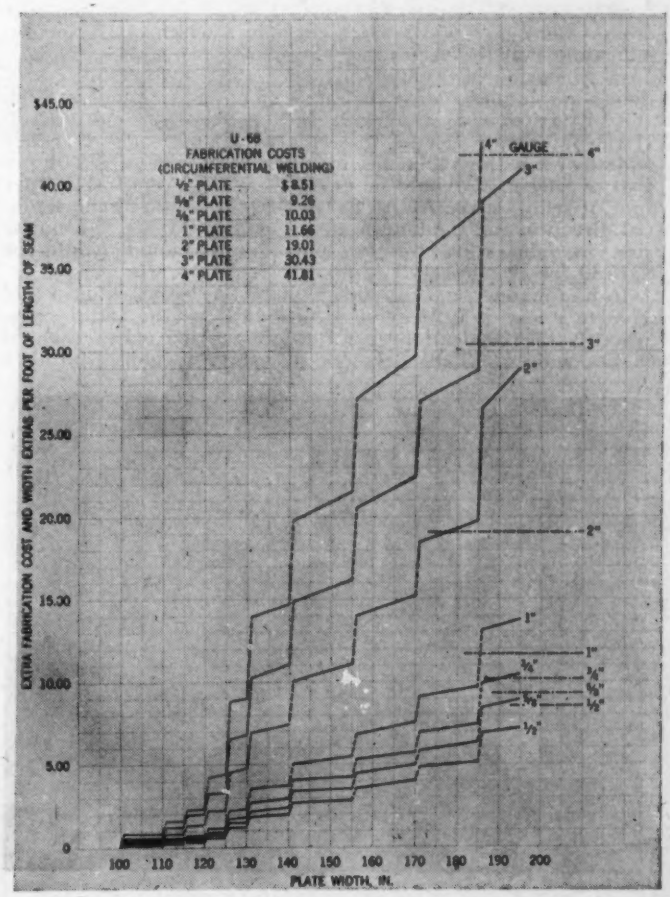


FIGURE 10

FIGURE 11

applicable also to longitudinal welding. As a consequence of the more favorable position in which the welding is performed, the fabrication cost for longitudinal welding is slightly lower, and the curves in Figure 9 would be somewhat lower for longitudinal welding. Costs for U-68 longitudinal welding as compared with circumferential welding are given in Table 2.

To simplify the comparison of width-extras and fabrication cost, the width-extras have been converted to cost per foot of length of plate as given in Figure 10. The fabricating costs are shown on the graph by broken horizontal lines at levels corresponding to the values tabulated on the chart for various gauges of plate. These costs are based on the data given earlier. If a fabricating cost differs from the value tabulated, a horizontal line should be drawn at a level representing that cost and the point of intersection with the corresponding width-extra curve should be determined. This point gives the optimum width of plate for that fabricating cost.

With a 1-inch plate having a fabricating cost of $11.66 per foot, Figure 10 indicates that the width of plate should be as great as the design permits up to 185½ inches. With a 2-inch plate, at a fabricating cost of $19.01 per foot, the cost crosses the 2-inch-width-extra curve at a width of 179 inches, indicating that the use of any two-plate construction to make up a dimension of less than 179 inches would be more costly than a single-plate construction. A single plate 2 inches thick and 140 inches wide would cost $7.50 per foot for width-extra. If the fabricator elected to weld two plates each 70 inches wide to form the 140-inch-wide shell, at a cost of $19.01 per foot of length, he would be doing so at the loss of $11.51 per foot of seam. If the length of the plate is in the circumferential direction and the length of the seam is 30 feet, the excess cost in fabricating the two-piece construction would be $345.30 for the vessel.

In like manner, a 2-inch-thick plate 108 inches wide would involve a cost of $0.38 per foot of length for the width-extra, whereas the fabrication cost for joining two plates each 54 inches wide at $19.01 per foot of length would result in a loss of $18.63 per foot of length. This illustrates the necessity of using the greatest possible width of plate that the fabricating cost will permit, if heavy additional fabrication costs are to be avoided.

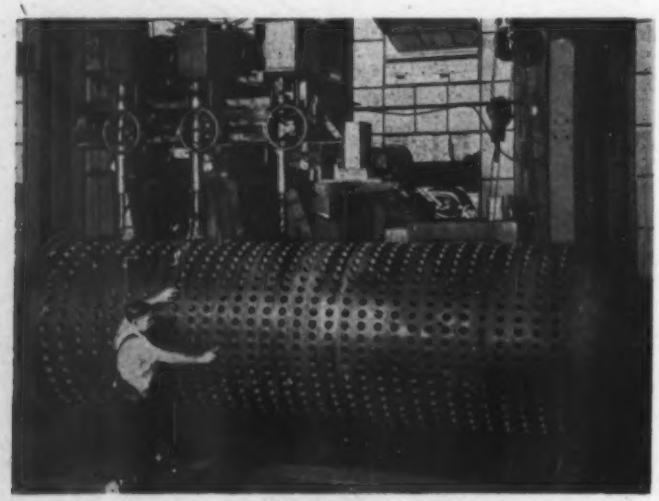


FIGURE 12

It will be noted from Figure 10 that in ⅝-inch gauges and lighter, and with the fabrication costs given in the chart, the one-piece construction is cheaper than the cost of fabrication for all widths. In ¾-inch plate, the one-piece construction is more economical up to 190 inches width, the 1-inch plate up to 185½ inches, the 2-inch plate up to 177 inches, and the 3-inch and 4-inch thicknesses up to 185 inches.

Curves for intermediate gauges may be plotted as desired on Figure 10.

An analysis of a recent order for 20 48-inch and 20 54-inch vessels is enlightening. These shells (shown in their finished state in Figures 11 and 12) might have been ordered as follows:

48-Inch Diameter Vessels
20 Plates 157½ × 87 × 1¾ inches
20 Plates 157½ × 85 × 1¾ inches
54-Inch Diameter Vessels
20 Plates 176¾ × 91 × 1-15/16 inches
20 Plates 176¾ × 93 × 1-15/16 inches

After comparison of width extras and fabrication costs, the fabricator placed his order as follows:

48-Inch Diameter Vessels
20 Plates 171 × 157½ × 1¾ inches
54-Inch Diameter Vessels
20 Plates 183 × 176¾ × 1-15/16 inches

With the two-plate construction the extra fabricating cost, using the fabricator's own figures, was estimated to average $436.00 per shell, or a total for the 40 vessels of $17,440.00. With one-plate construction the extra for the 40 wide plates at width-extras of $1.25 per 100 pounds for the 157½-inch-wide plate and $1.50 per 100 pounds for the 176¾-inch-wide plates, and the overweight allowance, totaled $9,853.00. By 20 minutes' calculation, a net saving was effected of $7,587.00 in the fabrication cost for the 40 vessels. In addition, by eliminating the extra fabricating operations which would have been required by two-piece construction, fabricating time on the 40 vessels was reduced by 5800 manhours, or the equivalent of a 48-hour work week of 121 men. There results a corresponding increase in shop productivity without additional expenditure for plant or equipment.

The simplicity of the construction used in these 40 vessels, as shown in Figures 11 and 12, indicates the freedom afforded the designer of the vessels in the location of tube holes and other openings without interference by a circumferential weld.

Multiple-Course Construction

A similar analysis may be made for a cylindrical vessel in which its length is greater than the widest plate which can be rolled, namely 195 inches; in such a case, the length of the plate, as rolled, forms the circumference of the vessel, and the width of the plate becomes part of the length of the shell. For example, the diameter may be 10 feet and the length 18 to 26 feet. Two-piece and three-piece constructions of such

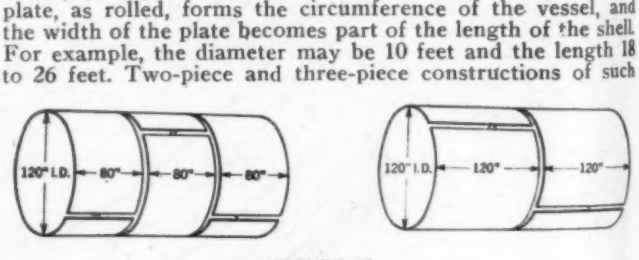


FIGURE 13

a vessel are shown in Figure 13. With three-piece construction an additional circumferential seam has to be fabricated; the additional fabricating cost is shown in Figure 14.

A 20-foot-long drum may be made of two courses each 120 inches wide or three courses each 80 inches wide, as shown in Figure 13. The 120-inch plates save the fabricating cost of one seam, and cost a total width-extra for the two plates of $59.30. With three 80-inch plates, 1 inch thick, the cost of making the additional circumferential seam is $11.66 per foot or a total of $380.93. All figures used herein include normal overweight allowances, metal and width-extras, involved in the overweight. The wide-plate construction saves the difference between these two costs, or $321.63 per vessel. In addition 127 manhours have been saved in fabricating the vessel with wide plates.

With increase in the lengths of the shells wider plates are required for the two-piece construction and the width-extra cost may approach the extra fabricating cost for the three seams. However, in each case 127 manhours of fabricating time are saved on each vessel by the use of the two-plate construction. The maximum width used economically for

1-INCH GAUGE

Plotted values of the variation cost with the number of courses for a 120-inch-inside-diameter shell, for lengths from 18 to 64 feet.

The shell is made of 1-inch-gauge plate and the cost of a circumferential weld is taken as $11.66 per per foot (U-68 type construction).

The stated costs include only width extras, overweight allowances and the additional fabrication cost resulting from more courses than the minimum number which is required by the widest available plates.

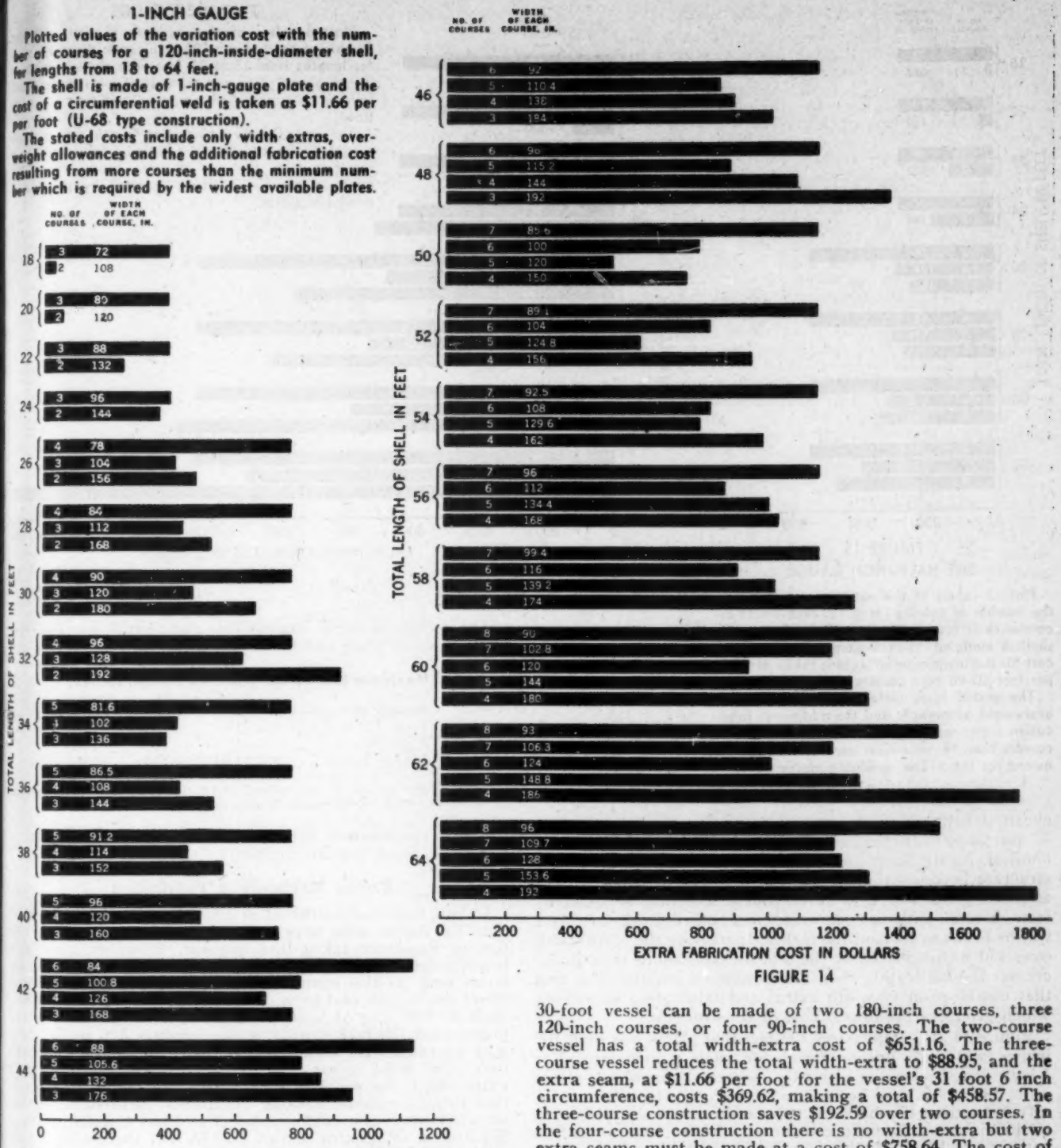


FIGURE 14

1-inch-thick plate in the two- or three-course construction is about 155 inches. It is uneconomical to use plates under 100 inches wide in any of the combinations.

The economic advantage of wide plates varies with the number of courses used in a vessel. As the number increases beyond three courses, the actual saving in cost, effected through the use of wider plates, becomes less. This results from the fact that the widest possible plates carry high width-extras and cost so much that considerable fabrication can be done for less than the width-extra cost. It is nevertheless always true that the use of wider plates reduces the manhours of labor required for fabrication of the vessel, thereby speeding output and increasing production volume and plant capacity without additional investment in plant or equipment.

In Figure 14, the four vessels, varying from 26 feet to 32 feet in length, may be made up of either two, three or four courses. The bar charts show the total cost either of width-extra or of extra fabrication, or a combination of both. The three-course construction is then seen to be cheapest. An example of the procedure in calculating is as follows: the 30-foot vessel can be made of two 180-inch courses, three 120-inch courses, or four 90-inch courses. The two-course vessel has a total width-extra cost of $651.16. The three-course vessel reduces the total width-extra to $88.95, and the extra seam, at $11.66 per foot for the vessel's 31 foot 6 inch circumference, costs $369.62, making a total of $458.57. The three-course construction saves $192.59 over two courses. In the four-course construction there is no width-extra but two extra seams must be made at a cost of $758.64. The cost of the four-course construction is greater than for two courses, and much greater than for three courses.

Figure 14 also shows the cost for shell lengths from 34 to 64 feet for a diameter of 120 inches and 1-inch gauge. The selection of the optimum construction is not affected by the diameter of the shell since both the total width-extra costs and the circumferential seam fabrication costs vary in direct proportion to the diameter.

The most economical width of plate can be seen from these bar charts. For the 50-foot vessel, the five-course construction with 120-inch plates, which require an additional circumferential seam as compared with the four-course construction, is lowest in cost. The four-course unit involves a total width-extra of $736.44; the five-course construction costs $517.87 for width-extra and additional fabricating cost. The six-course vessel involves an extra welding cost of $739.24 due entirely to the cost of the two additional seams plus $36.36 for the extra metal involved as overweight for a total of $775.60. The sum of $1,141.13 for the seven-course unit is the cost of the three extra seams.

Figure 14 shows that the four-course construction is

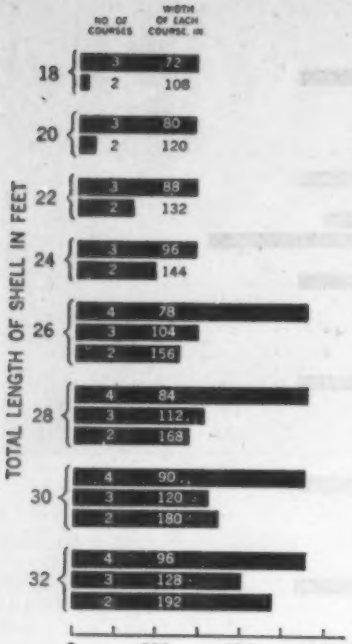


FIGURE 15

ONE-HALF-INCH GAUGE

Plotted values of the variations in cost with the number of courses for a 120-inch-inside-diameter shell, for lengths from 18 to 32 feet. The shell is made of ½-inch-gauge plate and the cost for a circumferential weld is taken at $8.51 per foot (U-68 type construction).

The stated costs include only width extras, overweight allowances and the additional fabrication cost resulting from the use of more courses than the minimum number which is required for the widest available plates.

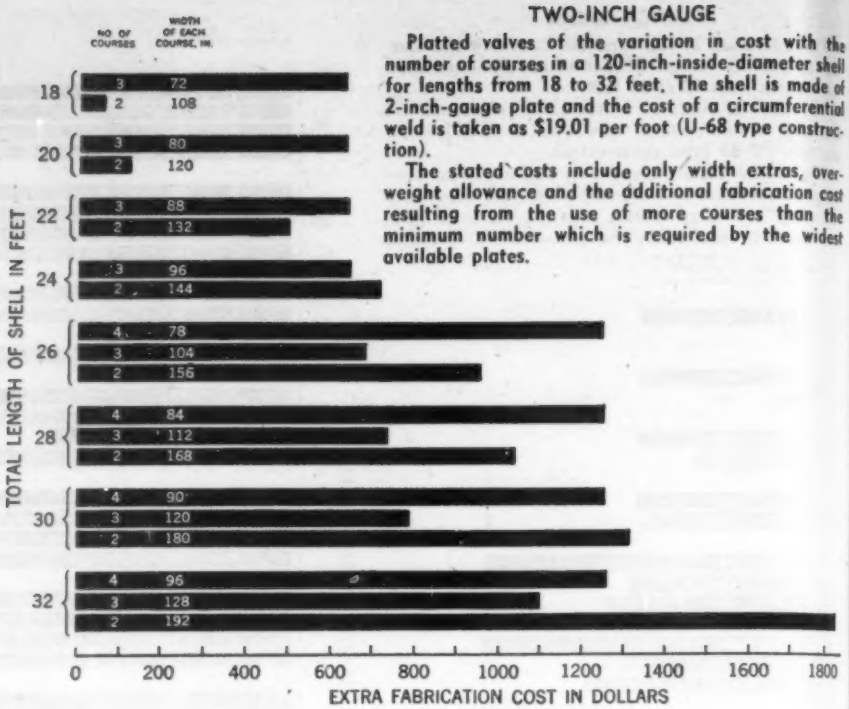


FIGURE 16

TWO-INCH GAUGE

Platted valves of the variation in cost with the number of courses in a 120-inch-inside-diameter shell for lengths from 18 to 32 feet. The shell is made of 2-inch-gauge plate and the cost of a circumferential weld is taken as $19.01 per foot (U-68 type construction).

The stated costs include only width extras, overweight allowance and the additional fabrication cost resulting from the use of more courses than the minimum number which is required by the widest available plates.

cheapest between the lengths of 36 feet up to and including 42 feet, and then the five-course type becomes most economical. As the length of the vessel increases, the six-course structure becomes the cheapest, at a length of about 56 feet and this gives way to a seven-course structure at about 64 feet. These optimum constructures correspond to plate widths between 100 and 130 inches. Increasing the plate width over 130 inches increases the width-extras more than it decreases the fabricating cost. The designer's problem is to find that combination of width extras and fabricating operations which produces the lowest cost of construction.

Figure 14 also emphasizes the fact that plates less than 100 inches wide are uneconomical for such a structure. For 1-inch gauge where one or two courses are involved, plates up to 185 inches may be used to advantage; where the choice of construction lies between two or three courses, plates up to 155 inches are most economical; where three or more courses are involved, the economical limit is scarcely more than 130 inches.

Similar cost data for ¼-inch and 2-inch gauge are presented, in Figures 15 and 16, and indicate analogous relationships for vessel construction in these gauges.

Considering the ½-inch gauge and 10-foot diameter, if the choice is between two wide plates and three narrow ones (with the fabrication cost of the circumferential weld at $8.51 per foot), the three-course construction exceeds the cost of the two-course type up to approximately 175 inches. As the length of the vessel increases, the three-course vessel is seen to be lower in cost than either the two- or four-course construction. As with the 1-inch gauge the optimum width for three or more courses is between 100 and 130 inches.

For the 2-inch gauge combinations as shown in Figure 16, the trend is similar but the limits in the two- or three-course vessel constructions are at a slightly lower plate width than either the ½-inch or 1-inch gauges, namely 140 inches. Where the length of the vessel may be made up of two, three or four courses from plates of corresponding widths, the most economical width does not exceed 130 inches.

The following table summarizes the results for different thicknesses of plate and number of courses:

Maximum Economical Width of Course, Inches

Number of Courses	½-in. Plate	1-in. Plate	2-in. Plate
1 or 2	195	185	176
2 or 3	175	155	140
3 and more	*130	*130	*130

* Where the saving in manhours of fabrication time is important, these widths may be substantially increased.

Every combination should use plates over 100 inches in width for the maximum economy.

Saving Manhours in Fabrication

In long vessels constructed of multiple courses, plates more than 130 inches wide appear to be at a disadvantage if cost figures alone are taken into account. However, the other benefits derived from their use, such as the reduction of manhours and of the equipment needed for fabrication, may offset the higher cost of wider plates. Consider a cylindrical shell 30 feet long of ½-inch gauge. It may be made of two plates each 180 inches wide, or three plates 120 inches wide with an extra weld seam, or four plates 90 inches wide with two extra weld seams. For the two-course shell the only extra cost is the width-extra applicable to 180-inch plates, in this instance totaling $343.66. The three-course shell requires an additional seam costing $268.49 and has a width extra of $51.96 or a total extra cost of $320.45. The three-course shell saves only $23.21 in comparison with the two-course shell, but requires 89 more manhours in fabrication to effect this small economy, or, two men were employed for a 45-hour week to save $23.21. If these two men had been employed in the production of additional vessels a greater income would be obtained as a result of the increase in production.

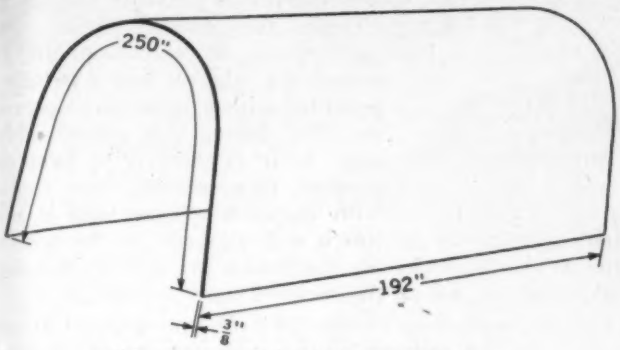
In like manner, the 64-foot-long drum of 1-inch-thick plate shown in Figure 14 indicates the seven-course combination to be lowest in cost. It is less costly than the six-course vessel by approximately $24.00 and cheaper than the five-course one by about $109.00. However, compared with the four-course construction (which is undoubtedly too expensive except under unusual conditions), the extra fabricating time is 123 hours for the five-course unit, 246 hours for the six-course unit and 369 hours for the seven-course vessel.

The waste of the additional 123 manhours needed to effect the saving of $24.22 in money by using the seven-course vessel is only outweighed in careless estimating by the saving of $109 at the cost of 246 more manhours of fabrication time by failing to select the five-course 154-inch-wide plates. The estimating engineer should consult his manpower reserve as

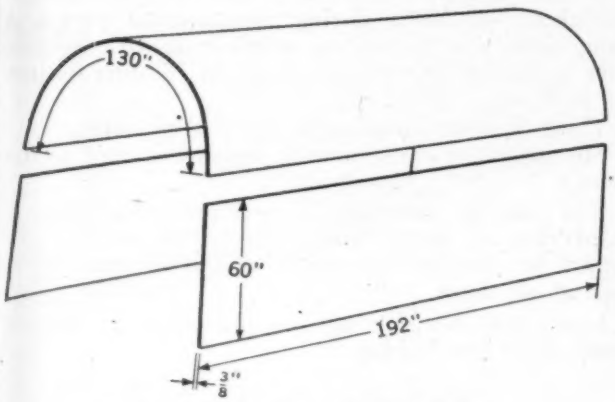
well as his firm's cash in selecting the right combination of plates in the design of a vessel.

One fabricator, by the use of one 154-inch-wide plate instead of two 77-inch-wide plates, increased his production from 15 vessels to 20 vessels per week, or an increase in production of 33⅓ percent without additional investment in men, machinery, or plant.

Where welded joints in vessels have to be inspected in the field after certain periods of operation, wide plates, by reducing the number of seams, keep such service costs at a minimum.



1 Plate 250 x 192 x ⅜ in. = $122.66 Width Extra



1 Plate 192 x 130 x ⅜ in. =	$ 18.04	Width Extra
2 Plates 192 x 60 x ⅜ in. =	1.84	Overweight
32 Ft welding @ $7.20/ft =	230.40	Fabrication
Total	$250.28	
Cost of One-Plate Width Extra	122.66	
Net Saving with One Plate	$127.62	

FIGURE 17

Allowable Overweight of Plates

The "allowable overweight" of steel plates has sometimes been considered as an objection to the use of wide plates. As the width of the plate increases up to 168 inches the allowance for overweight likewise increases. From 168 to 195 inches the percentage overweight allowance remains constant.

The cost of wide plates is increased by this overweight, but this increase is a small fraction of the savings in fabricating costs and manhours resulting from the use of wide plates. The following example illustrates this point in a vessel that could be built either of two plates 240 x 144 x ½ inches or of three plates 240 x 96 x ½ inches. The increased overweight allowance for the two 144-inch plates is $20.54, including the base price, quality-extra and width-extra involved as a result of this overweight. This overweight cost plus the width-extra cost for the two 144-inch plates over that of the two 96-inch-wide plates is $118.48. The extra fabricating cost plus overweight for the three-course construction is $178.78. The 144-inch plates, despite the greater overweight allowance, show a net saving of $60.30 per vessel.

Width-Extras and Low-Alloy Steels

The preceding considerations determining optimum plate widths apply equally to plates of low-alloy steel. The width extras for such steels are somewhat higher in proportion to their fabricating costs; the maximum economic width is found to be approximately 10 percent lower than the carbon steels.

Plate Widths in Clad Steels

The use of wide plates of clad steels shows even greater savings than with the carbon steels, as both the base price of the material and the fabricating costs are higher in proportion to the width-extras for the clad steels. The fabricating costs are increased by the care necessary in working the clad materials, and by the cost of the accessory metals such as welding electrodes.

With clad steels, the widest possible plate should always be used; all known examples show savings.

A comparison of width-extras and welding costs for 10-percent-nickel-clad steel, converted to costs per pound of plate material used, is shown in Figure 17. For example with a ½-inch-gauge plate farbricated in accordance with U-68 requirements at $11.80 per foot, the extra fabricating cost using two 42-inch plates to make up an 84-inch plate by welding would cost $0.078 per pound; a single plate 84 inches wide would cost $0.005 per pound in width-extras. This results in a saving of $0.073 per pound or almost half of the base price of the material, in addition to the other advantages of time, and manhours. As a further illustration, a single plate 108 inches wide would have a width-extra cost of $0.010 per pound and the fabricating cost to join two 54-inch plates of ½-inch gauge and built by U-69 construction would cost almost $0.038 per pound. The saving by using the single wide plate would be $0.028 per pound.

Similar curves for stainless-clad steels are given in Figure 19. From these it may be seen that a single plate 108 inches wide can be purchased for a width extra of $0.015 per pound; two narrow plates, 54 inches wide, of ⅜-inch gauge, have a U-69 fabricating cost of $7.37 per foot and would cost $0.0509 per pound to join together. The use of the wide plate effects a saving of $0.0359 per pound as well as the savings in shop time and use of equipment.

Solid Stainless and Non-Ferrous Metals

The high-priced solid stainless and non-ferrous metals show similar savings for wide plates. A single wide plate 84 inches wide and ½-inch gauge may be purchased for a width-extra of $0.01 per pound. Two narrow plates each 42 inches wide and welded to form a plate 84 inches wide would cost $0.0468 per pound for the extra fabrication required by U-69 construction at $7.41 per foot. The saving due to wide plates in this case is $0.0369 per pound.

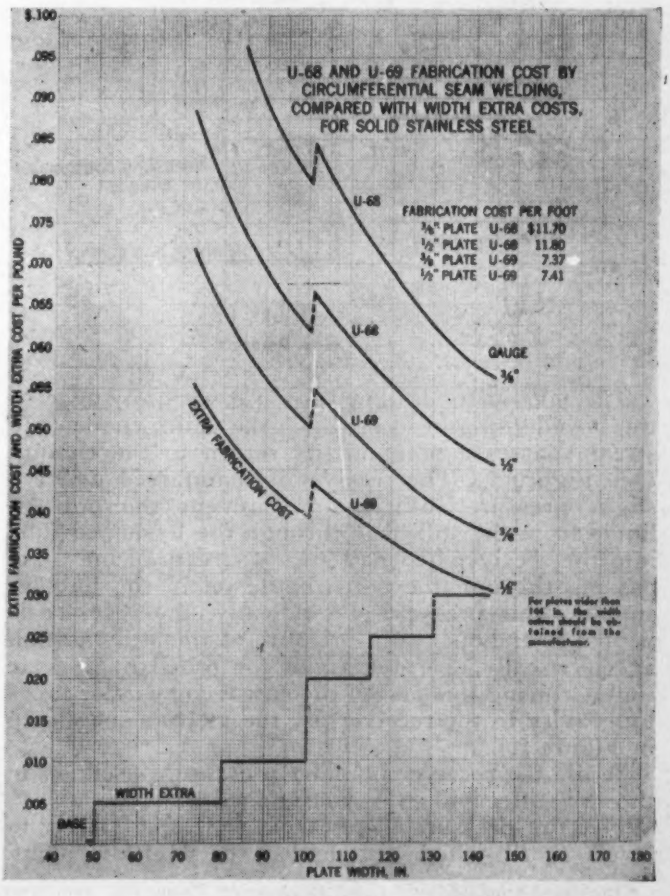


FIGURE 19

Simple Constant Reflux Take-off For Distillation Systems*

JOHN C. SNYDER and WALTER STEUBER
Catalytic Development Corporation, Marcus Hook, Pennsylvania

IN LABORATORY fractional distillation it is often necessary to control the reflux ratio so that it is kept constant, regardless of variations in the distillation rate or empirical factors. This has been accomplished by Carter and Johnson[2] with a magnetically moved funnel, by Bruun[1] with a two-way valve and capillaries, and by Podbielniak[3] with an automatic valve seated in the take-off tube. All these devices require a degree of skill too great for fabrication by an amateur glass blower, and various mechanical difficulties have been experienced in their operation, due to sticking of moving parts or plugging of capillaries. An easily constructed take-off device of the intermittent type which operates smoothly is described in this paper.

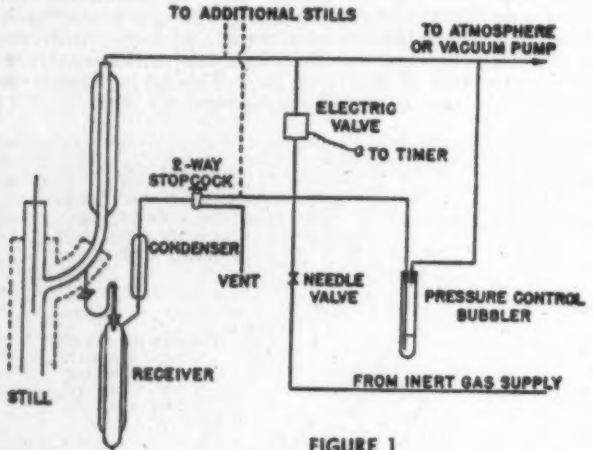


FIGURE 1
Flow Diagram

The take-off is designed for use with any type of total condensing head in which the entire condensate stream passes a point on its return to the column (see Figure 1). The receiver is maintained under a slight pressure sufficient to prevent the flow of liquid from the still head through the U-shaped tube into the receiver. A small steady stream of inert gas passing through the non-volatile oil in the bubbler supplies this pressure. Periodically, the receiver is vented to the operating pressure of the still through an electrically operated valve controlled by a cycle timer. During this period the entire condensate flows by gravity to the receiver, by the mechanism shown in Figure 2.

While the receiver is under pressure, the liquid in the take-off capillary is maintained at levels A, A'. When the pressure is released, the liquid flows to levels B, B', which are just at the overflow point. Consequently, all reflux during the "on" period enters the take-off at A and an equal amount of liquid overflows at B' into the receiver. At the end of the "on" interval (generally from 2 to 5 seconds), the valve closes and restoration of the receiver to pressure quickly interrupts the take-off stream. For convenience in emptying the receiver, the take-off line generally is provided with a stopcock to prevent the flow during this period. However, if it is desired to keep the product from coming into contact with stopcock grease, and if low-boiling components which will vaporize in the take-off line at the outset of the distillation are absent, this stopcock and the one on the receiver may be omitted.

The dimensions of the take-off line depend mainly upon the throughput of the still, but are not critical. The diameter must be sufficient to accommodate the entire distillate during the take-off period. A convenient length for Δh, which indicates the pressure head that is maintained by the bubbler, is from 0.5 to 3 cm.

The following advantages have been noted:

Simplicity of construction, operation, and adjustment.

The take-off maintains a constant reflux ratio, irrespective of distillation rate, which is preedtermined by simple adjustment of the intervals of an on-and-off timer.

Low cost. No delicate moving parts in the still head. Very low holdup.

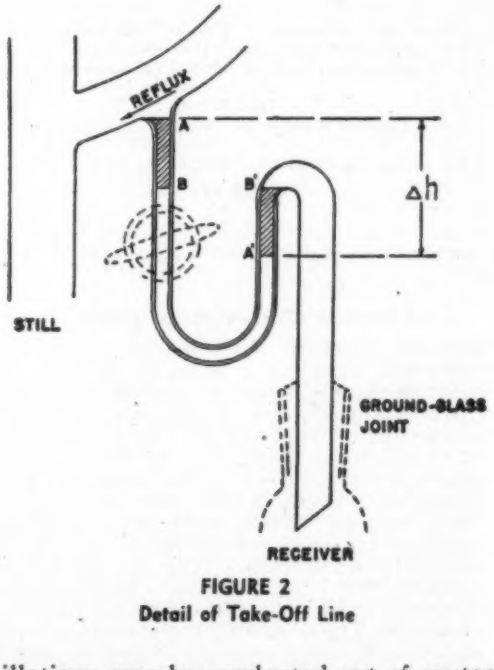


FIGURE 2
Detail of Take-Off Line

Distillations may be conducted out of contact with anything save glass and an inert gas. The method is adaptable to distillation at other than atmospheric pressure. Several stills may be operated with the same control system.

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[2] Carter, A. S., and Johnson F. W. (to E. I. du Pont de Nemours and Co.) U. S. Patent 2,251,185 (July 29, 1941).
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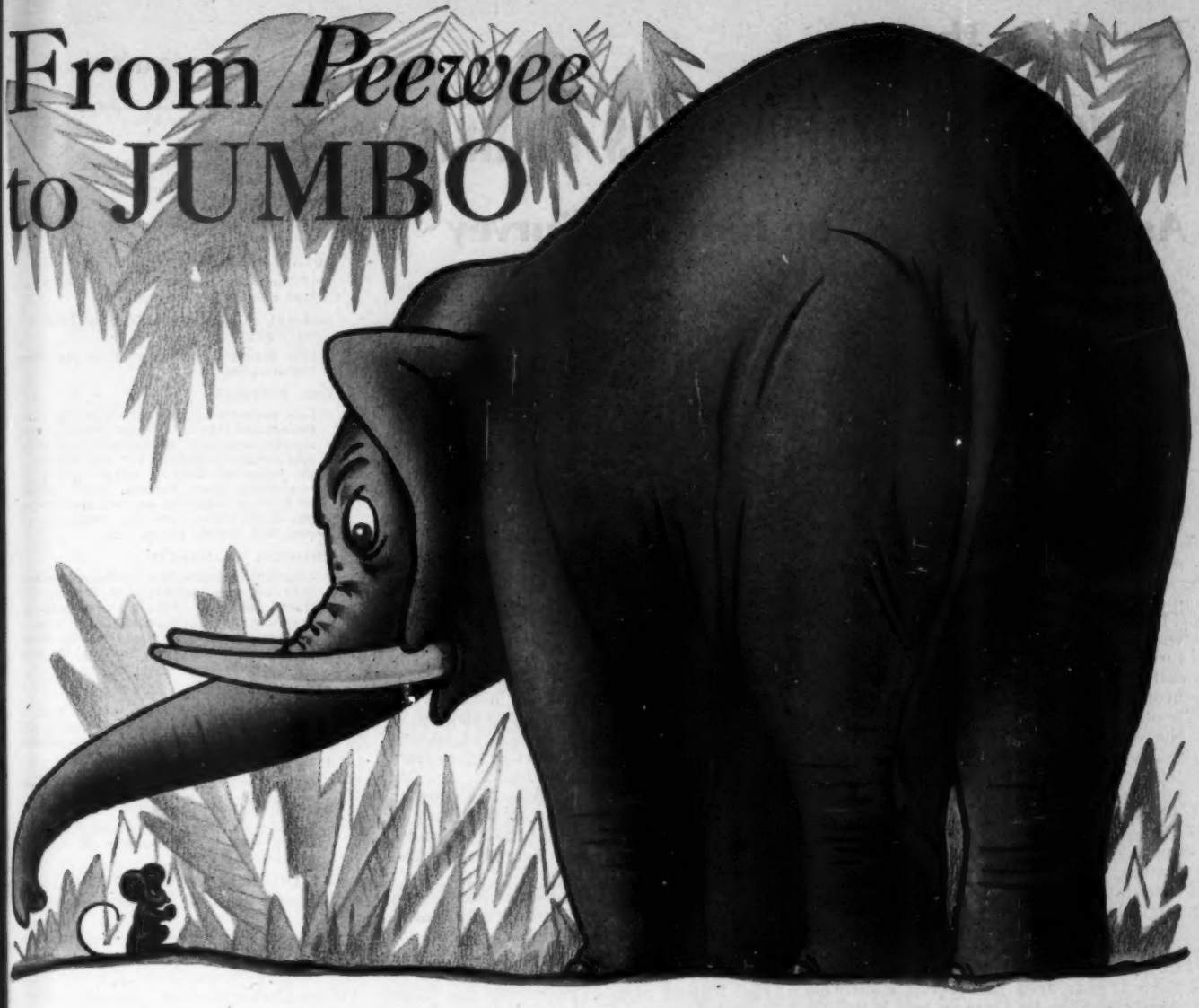
* Reprinted from Industrial and Engineering Chemistry, Analytical Edition, 16, 7, 454, July, 1944.

From *Peewee* to JUMBO



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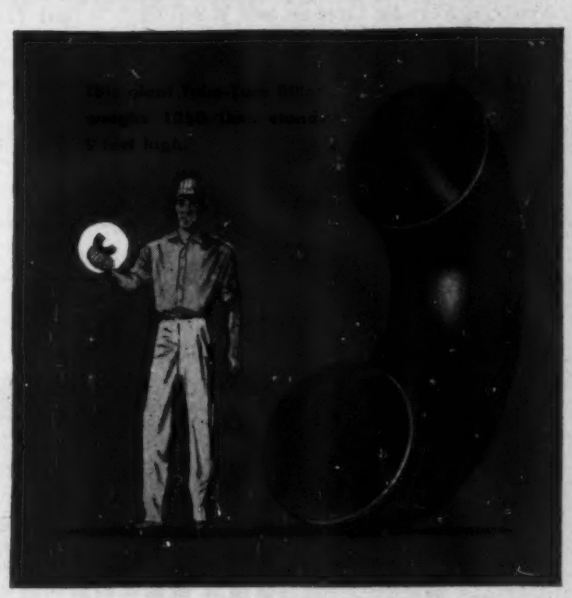

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Trends in the Liquefied Petroleum Gas Industry

As Reflected by the Industry Survey

PAUL K. THOMPSON, Chief, Liquefied Petroleum Gas Section
Petroleum Administration for War

CONTINUED use of liquefied petroleum gas as a fuel and a source of energy, together with its more recent application as a raw material in the production of aviation fuel, synthetic rubber and chemicals, has placed this product foremost in the class of critical materials. Possibly the use of no other petroleum product has developed so rapidly as the separate fractions and mixtures of propane and the butanes. The greatly accelerated war use of LPG was definitely confirmed during the winter of 1943-44 when transportation difficulties, together with localized shortages, brought about by necessary diversion of products as war materials, precipitated the worst winter in the history of LPG. Early in the spring of 1944, it appeared that a similar condition would be encountered during the winter of 1944-45. Thus, to make available all possible information relating to the supply and demand of LPG, the Petroleum Administration for war requested industry representatives to determine as nearly as possible these conditions in PAW Districts 1, 2, 3, and 4 for 1943, 1944 and the first six months of 1945. Similar information was already available for District 5, that area embracing California, Arizona, Nevada, Oregon and Washington.

This paper will discuss the service performed by the special LPG survey joint subcommittee in preparing this report, making available for publication such portions of this study as wartime security permits in addition to commenting on related factors such as government regulations, distribution, etc., endeavoring to analyze these factors in the light of what may be expected in the immediate future, together with the developments which may result with the return to normal times.

James E. Pew, director of the Natural Gas and Natural Gasoline Division, Petroleum Administration for War, called a joint meeting of the LPG subcommittees of PAW Districts 1, 2, 3, and 4, which resulted in the organization of a special LPG survey joint subcommittee. This committee includes, as industry representatives, the chairmen of the district LPG subcommittees, as follows: G. R. Benz, District 2, chairman; Louis Abramson, District 3; R. W. Leslie, District 4, and W. A. Naumer, District 4. E. M. Peterson, secretary of District 2 Natural Gas and Natural Gasoline Committee, is secretary of this committee.

This committee was requested by PAW to ascertain as nearly as possible the relation between supply and demand of liquefied petroleum gases for 1943, 1944 and the first six months of 1945 in the United States, excluding the West Coast (District 5). In carrying out this request, a questionnaire was prepared by the committee for the purpose of securing information on both the production and disposition of liquefied petroleum gases. To ascertain the actual and estimated potential production for the period in question, a form was developed which when properly filled out gave the requested information for (1) propane,[1] (2) normal butane, (3) isobutane, (4) butane-propane mixtures and (5) normal butane-isobutane-butylene mixtures. In determining the disposition of products, a separate form for each of the above products was developed to indicate that amount for (1) fuel purposes,[1] (2) chemical manufacture, (3) refinery use, (4) isomerization feed, (5) synthetic rubber components, and (6) potential excess production.

Information was received from 18 companies—6 companies did not reply in any way to the questionnaire or the follow-up communications.

Information from 210 Plants

The information as supplied by the 110 companies representing 201 different plants was summarized and reported graphically by the committee. In addition, comments and recommendations are contained in the committee's report to PAW.

The release of the complete report at this time, in which statistics for the last nine months of 1944 are estimated, may appear to some as coming at too late a date to be of maximum value. However, and to the contrary, PAW was continuously advised by the committee throughout the progress of the survey, and since the major portion of the work was completed during the summer, the resulting information has

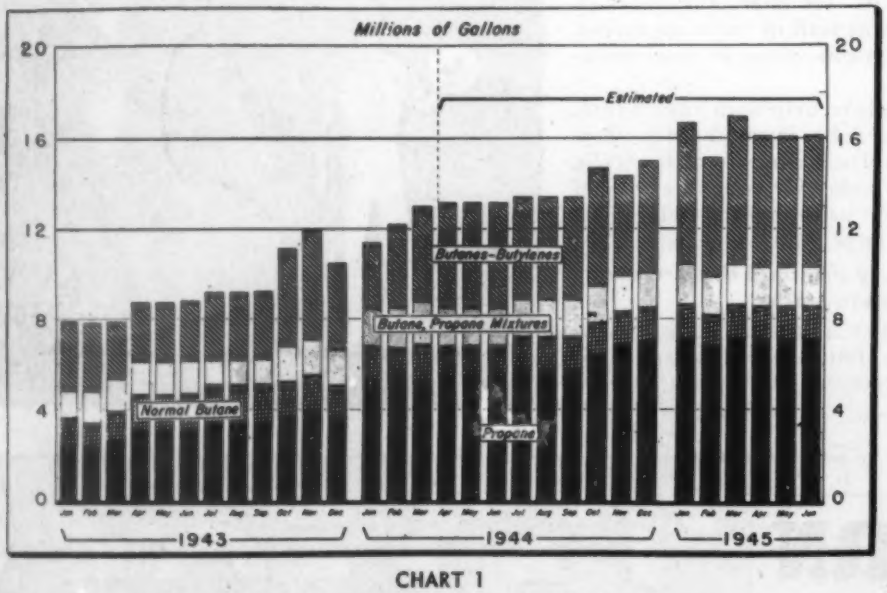

CHART 1
Use of Liquefied Petroleum Gases for Chemical Manufacture
(Does not Include Pacific Coast area)

GLOSSARY

PROPANE
LPG products containing 90 percent or more propane and/or propylene.

NORMAL BUTANE
LPG products containing 90 percent or more normal butane.

ISOBUTANE
LPG products containing 90 percent or more isobutane.

BUTANE-PROPANE MIXTURES
LPG products containing more than 10 percent propane and/or propylene.

NORMAL BUTANE-ISOBUTANE-BUTYLENE MIXTURES
LPG products not included in the above classifications.

FUEL PURPOSES
Fuel purposes include the following: Continuous and standby uses for domestic, commercial, industrial, agricultural, and utility applications including but not limited to the following: cooking, water heating, refrigerating, space heating, metal cutting, all kinds of industrial heating applications, gas manufacture, internal combustion engine fuel, drying, baking, etc.

CHEMICAL MANUFACTURE
Chemical manufacture includes products used as base materials or process feed stocks, additives, diluents, extenders, solvents for chemical manufacture or processing (except specific uses otherwise classified below), and for burning to make carbon black.

REFINERY USE
Includes all refinery use except that for isomerization feed stock. Includes LPG used for refinery fuel and blending purposes.

ISOMERIZATION FEED
Includes all isomerization feed stock uses.

SYNTHETIC RUBBER COMPONENTS
Includes all products to be used for processing into or manufacture of synthetic rubber components.

POTENTIAL EXCESS PRODUCTION
Product not going into the above uses.

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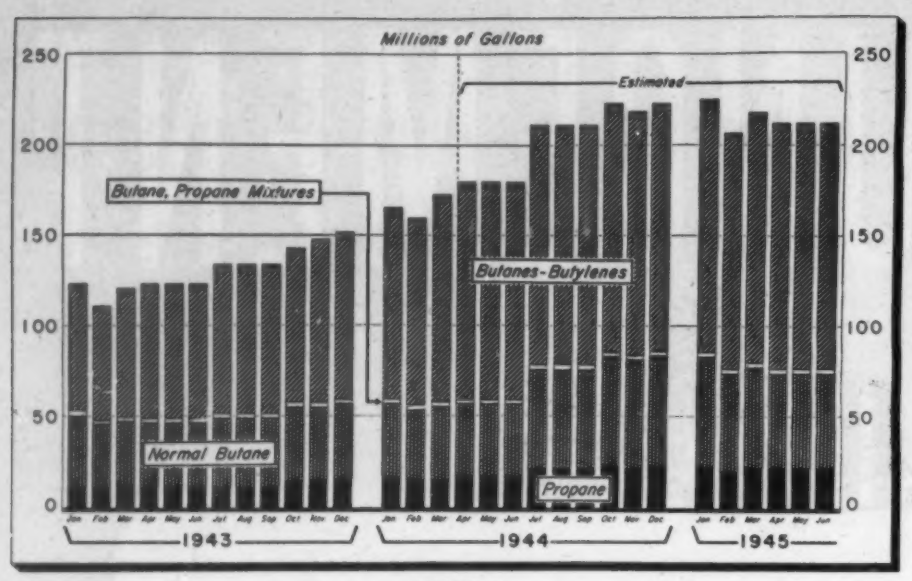

CHART 2
Refinery Uses of Liquefied Petroleum Gases
(Does not Include Pacific Coast area)

been of invaluable help in planning for the present winter. It is quite impossible to enumerate here the difficulties encountered by the committee in conducting this study, these difficulties being directly responsible for the apparent delay in its final presentation.

The LPG survey covered only the production and disposition of products. Naturally, related problems such as transportation, manpower and lack of equipment contribute to the success or failure of wartime distribution even though the required products are available. It was decided to limit this study, as previously noted, and rely upon information presently available to industry concerning distribution. Shortly after this study was under way, it was evident that such a decision was correct because it was necessary for the committee to exert all its energy to conduct and complete this work even at a late date. The many problems encountered by the committee did not affect the quality of their final report. The successful manner in which these problems were solved is partly reflected in their splendid report, a portion of which is discussed herein.

Chemical Raw Material

In analyzing the relationship of supply and disposition of LPG, widely different local conditions become apparent. Although such conditions contribute to the over-all picture, any single condition is not necessarily representative of the entire situation as reflected by such a survey. Too, ever-changing problems of transportation and storage added to the many other variables together make the present LPG fuel situation a problem of the most difficult proportions. These variables dictate that the release of information relating to the total production and use of LPG as fuel, would tend to distort the picture and result in false conclusions rather than to provide a basis for industry to solve its present problems. Accordingly, the use of LPG as fuel is only commented on herein, while its use as a chemical raw material, for refinery operations, and for synthetic rubber components is discussed graphically with actual and estimated yearly figures presented.

The growing trend of LPG as a chemical raw material is shown in Chart 1. The major components, presently employed for chemical use, are propane and butane-butylene mixtures. This study indicates that a total of 110,895,000 gallons of LPG, as a liquid, was used as a chemical raw material in 1943. The 1944 requirement is set at 159,788,000 gallons, an increase of 44 percent. It should be noted that these amounts are for that LPG shipped as a liquid only. Larger amounts of these gases are delivered to chemical plants in the gaseous form by pipe lines. A recent estimate[2] of the quantity of LPG used as a chemical raw material, delivered as liquid or gas in the United States, indicates that a total of 389,127,500-gallon equivalent was used in 1943. The 1944 requirement, with the latter nine months estimated, was set at a 478,022,000-gallon equivalent, an increase of 23 percent. This chemical use of LPG continues to grow with prediction of ever-increasing amounts of ethane-propane and propane-butane mixtures as raw material in processes employing regenerative cracking and catalytic oxidation, respectively.

Aviation Fuel

In the production of newer, better and greater quantities of aviation fuel and to continue to meet essential military and civilian requirements of various fuels and other petroleum products, large quantities of LPG are being used in refinery operations. In reporting the growing trend of LPG for refinery uses (Chart 2) security restrictions have necessitated that this classification include not only conventional refining demands but those for isobutane for alkylation and butane for isomerization purposes. This is necessary to eliminate any possible prediction relating to increased alkylate production. Nevertheless, the increased use of liquefied gas for total refinery uses reflects their growing importance in the production of aviation fuel components. In 1943, 1,558,209,000 gallons of LPG were used for refinery operations and 2,327,208,000 gallons estimated in 1944. This increase of 788,999,000 gallons (about 50 percent) is of interest when compared with the total sales of LPG in the United States for 1943 of 675,233,000 gallons as reported by the United States Bureau of Mines.[3] This large use of LPG in refinery operations can be expected until total victory. The termination of the war in Europe should not bring any reduction in the manufacture of key aviation fuel components such as isooctane alkylate, even though the total production of finished aviation fuel may be temporarily reduced until the concentration of the total war effort is esablished in the Pacific area.

Another burden placed upon butanes is their wartime role in the production of synthetic rubber. In achieving the required production of synthetic rubber, which has been recognized by many as the outstanding chemical achievement of the war, enormous quantities of light hydrocarbon gases are required as raw material. The contribution of LPG products is graphically portrayed in Chart 3. In the production of butadiene, one of the chief ingredients of synthetic rubber, large quantities of butane - butene mixtures are required. Thus, as in the case of isooctane alkylate, the production of synthetic rubber imposes large demands

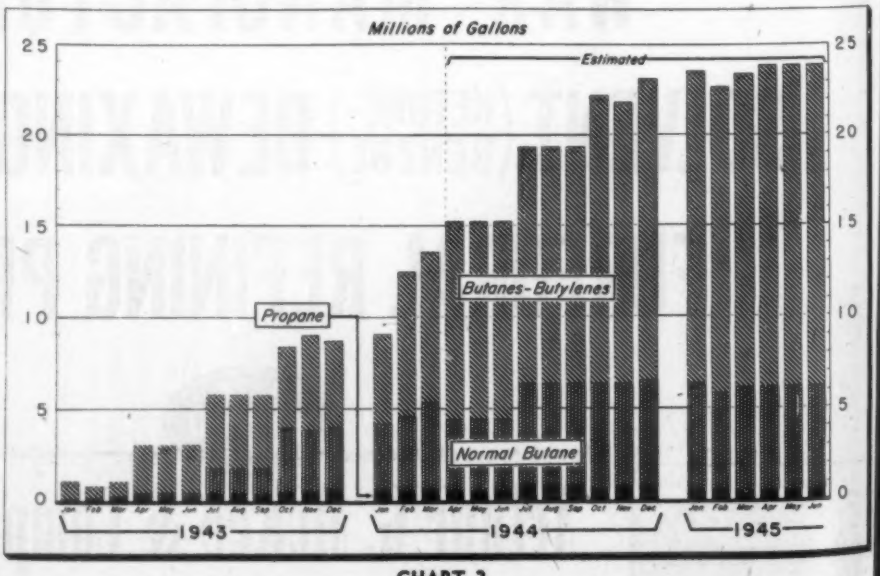

CHART 3
Use of Liquefied Petroleum Gases for Synthetic Rubber Components
(Does not Include Pacific Coast area)

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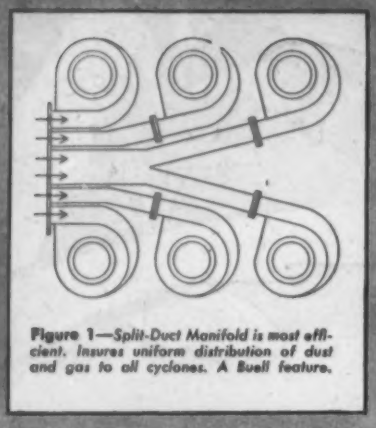
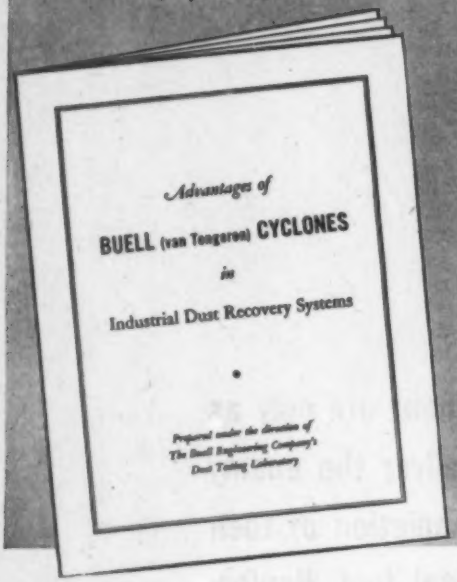


Figure 1—*Split-Duct Manifold is most efficient. Insures uniform distribution of dust and gas to all cyclones. A Buell feature.*

THE MOST EFFICIENT METHOD
(Buell's)

Figure 2—*Unit-Chamber Manifold. never used by Buell. Disadvantages: uneven distribution of dust to tubes, piling up of dust in rear of chamber, rapid erosion of outlet tubes.*

THE LEAST EFFICIENT METHOD
(Never used by Buell)



BOTTOM VIEW OF
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Every engineer and operating executive should have a copy of the bulletin shown above as his guide in the selection of the right dust collection equipment.

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Buell Design ELIMINATES CLOGGING MINIMIZES EROSION

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upon butanes. The survey reveals that 55,434,000 gallons of LPG were required for synthetic rubber production in 1943 and 205,457,000 estimated in 1944, an increase of 270 percent. Again, the future demands for LPG products for synthetic rubber components are similar to those previously mentioned in the production of aviation fuel in that no reduction in their use can be expected until total victory in Europe and the Pacific. Even with total victory, the nation's synthetic rubber plants may be expected to continue maximum production to fill backlogs of civilian requirements in addition to replacing large amounts of imported natural rubber until such time as natural rubber sources are once more revived and productive.

Propane for Fuel

As mentioned above, statistical and graphical data will not be given for LPG fuel uses. However, it is interesting to note that the survey clearly indicated a swing of significant magnitude to the predominance of propane over butane-propane mixtures for fuel uses. This abnormal relationship results, of course, from the temporary diversion of large quantities of butanes to war products. The fuel use of normal butane and spent refinery butanes throughout the period studied, continues to bear the same relationship to the use of propane and butane-propane mixtures, as in the past. The use of propane as fuel appears to have experienced the greatest increase of all LPG fuels, mainly because of the diversion of butanes. Accompanying this increase are the conventional moderate seasonal fluctuations. The widespread use of butane-propane mixtures as heating fuels results in more pronounced seasonal demands than are evident in the use of any other LPG product. The moderate increase in the use of LPG products for fuel, other than butane-propane mixtures and the slight increase in the use of the latter, clearly reflect the results of the necessary steps taken by government and industry to insure the availability of these components for use in the production of war materials.

The well known fact that ample propane exists at production sources was indicated by the survey. As previously pointed out, the survey did not report factually on the very serious distribution phases. The lack of distribution facilities precludes the classification of this potential supply as available supply for actual consumer demands.

The critical butane and butane-propane situation of the past winter, together with that of the present winter, is definitely confirmed by the survey. It should be noted that the survey indicates a greater shortage of butane and butane-propane mixtures for the winter period of 1944-45 than was experienced during the winter of 1943-44. The severity of the current shortages, as of December, 1944-January, 1945, of LPG for fuel is the direct result of lack of transportation facilities, mentioned above, and also of the lack of butane, which was clearly predicted by the survey as early as the summer of 1944.

Although the entire report cannot be released at this time for war security reasons, it is hoped that the industry will recognize the efforts of the committee and the value of the report submitted. The interest of the industry in such surveys is timely, and it would seem to be appropriate for a continuation of these

A Kidde portable extinguisher quickly smothers fire in a motor-generator set, without danger of shock or damage to insulation.

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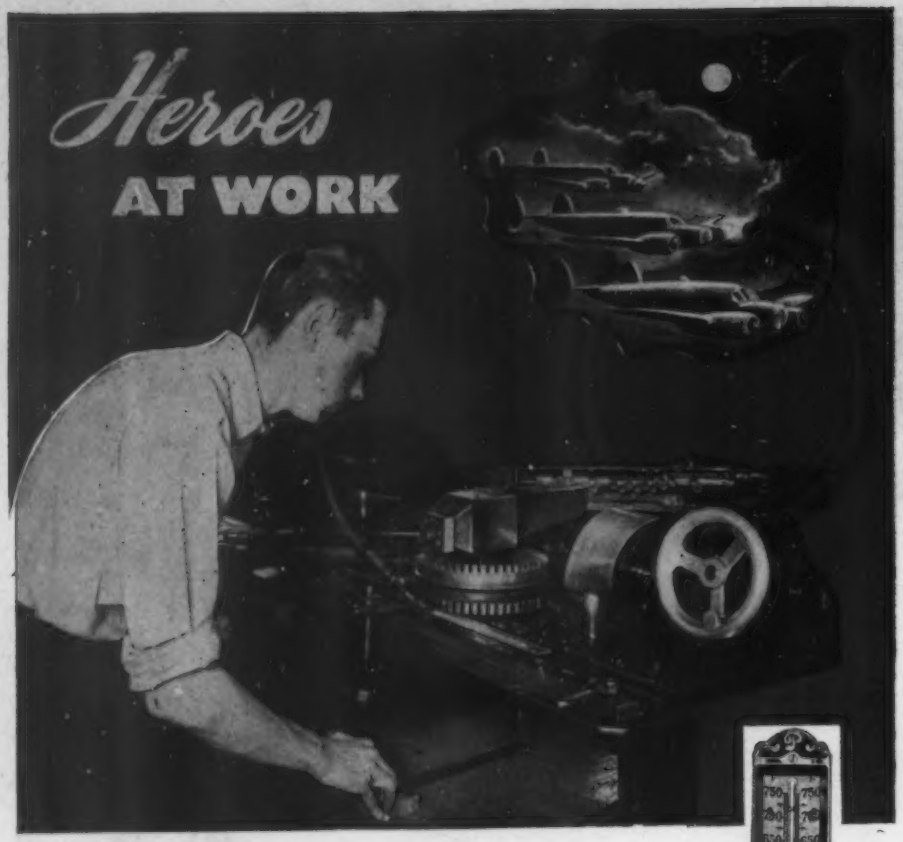

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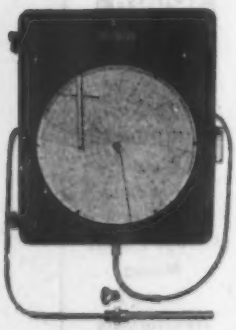

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And PALMER Thermometers give you:

1 . . . Precision and Guaranteed Accuracy

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3 . . . A bright RED column . . . so easy to see with "Red-Reading-Mercury."

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studies by the industry on the return to normal times when war agency requests for such work will not be forthcoming. In anticipation of present LPG problems continuing throughout 1945, PAW has requested the special LPG survey joint subcommittee to continue the study for an additional period. It is contemplated to expand the proposed study to include PAW District 5, thus making the survey nationwide in scope.

WPB Limitations

For over three years the operations of industry have been controlled and restricted by wartime regulations. The basic restrictions affecting the LPG distribution industry are those embodied in WPB Limitation Order L-86 and directions thereto. Broadly, Order L-86 prohibits delivery and installation of equipment used to contain, distribute, or dispense LPG. Direction 1 to Order L-86 restricts delivery and acceptance of delivery of LPG tanks. Direction 2 to Order L-86 prohibits delivery and acceptance of delivery of LPG for use as a motor fuel in private passenger automobiles.

The original purpose of Order L-86, when it was first issued April 8, 1942, was twofold: first, to conserve the then existing utilization equipment for the most important war uses; and, second, to conserve LPG itself so that war demands could be met, and also, insofar as possible, so that the requirements of existing LPG consumers could be satisfied.

As the demand for LPG for use in the production of war materials increased, the primary function of Order L-86 became the conservation of LPG, with the importance of equipment conservation becoming secondary but still quite necessary.

Administration of these regulations has attempted to accomplish the above purposes with a minimum of restrictions upon the industry. However, as the aviation gasoline and synthetic-rubber programs progressed, with the resulting requirements for LPG products, it became necessary to impose more restrictive measures. With the tentative report of the committee available in September, 1944, it was immediately evident that additional restrictions were necessary to meet the forthcoming conditions as predicted by the survey.

Thus on October 24, 1944, PAW announced issuance of Directive 79, which prohibits delivery or acceptance of delivery of butane for use as fuel in drilling operations where natural gas is available as a substitute fuel. This directive is effective during the present heating season, November 1, 1944, to April 1, 1945. During this time the quantity of butane that will be available for drilling operations will be limited because of the demand for this fuel by domestic consumers during winter.

Further, PAW announced, by press release November 24, 1944, that as of that date PAW would be compelled to disapprove all applications to install equipment utilizing butane or butane-propane mixtures.

As indicated by the preliminary report of the committee and substantiated by its final report, there was a shortage amounting to 4 to 7 million gallons per month of butane for all uses. This shortage was immediately felt by the LPG industry. With the cooperation of the refining division of PAW, the necessary steps to alleviate this condition were

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The non-contaminating property of "National" carbon, graphite and "Karbate" materials solves problems like this in many industries...

Non-contamination is assured, for example, using "National" carbon Raschig rings. It is of great importance to the success of chlorinating tubes for aluminum. "Karbate" scrubbing tower operations depend upon this quality. The same is true of carbon and graphite ingot molds, plugs and stools, or porous carbon filters.

But it is the unusual *combination* of physical, chemical and electrical properties that really gives "National" carbon, graphite, and "Karbate" materials their advantages over other materials. Inquiries are invited from the metals, chemical, mechanical, textile, electronic and other industries.

*Carbon or graphite made impervious to fluids under pressure.

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Carbon, Graphite, or "Karbate" materials, of course!

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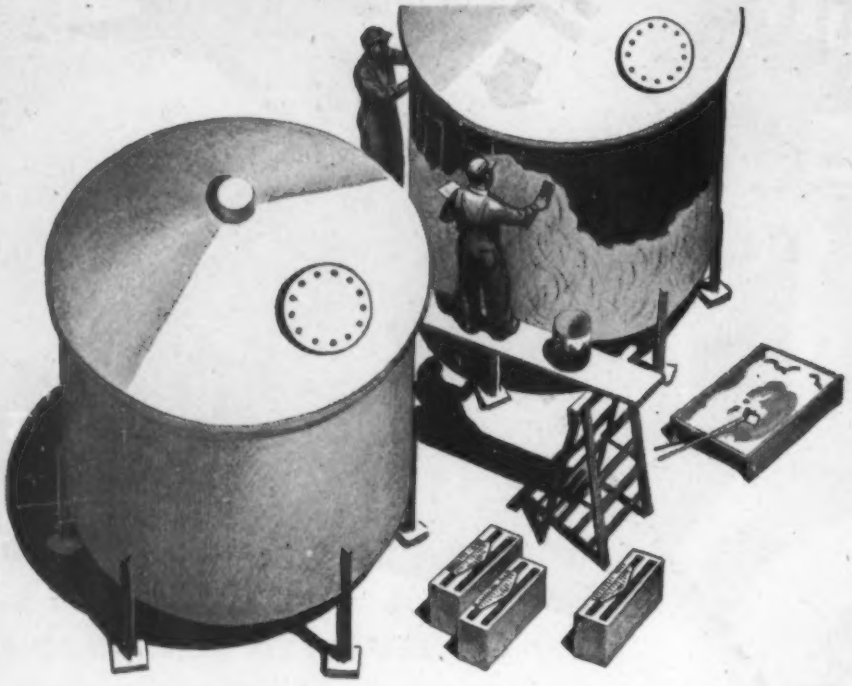

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The low alkalinity factor of the *black* rockwool fibres insures their stability under severe conditions of temperature, moisture and humidity.

This strong, but lightweight block cuts easily in straight lines or in odd shapes —yields readily to rivet heads or other surface irregularities. This means quick, sure application; when cemented with B-H Bond-Tite to a clean surface, wiring is often unnecessary. Mono-Block is supplied in a range of sizes and thicknesses . . . . Write for full information and generous sample.

For insulating cement that stays put—easy to apply on hot or cold surfaces—write for folder on B-H No. 1 Cement.

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taken to divert certain streams of mixed butanes from refinery use to LPG fuel markets.

Shortage May Continue

The present shortage of LPG products, the result of wartime demands, is a widely discussed subject. These discussions are not, in general, restricted to present conditions but in many cases predictions have been voiced that these shortages will continue even after the return to normal times. Some visualize a propane shortage; others predict continued difficulty in obtaining the desired amounts of butane. The discussion herein relating to LPG operations, on the return to normal times, is based upon an analysis of the survey committee's report, viewed in light of related information gathered in this division. The trend observed suggested that with the return to normal times, there will be a marked decrease in the demand for LPG products which are now required for wartime fuels and raw materials. Accompanying that decrease will be an increase in use as conventional LPG fuel, including the possible development and production of new fuels, and for chemical manufacture. Thus, an ever expanding LPG industry appears to be assured. There should be ample supplies of propane and butanes to be used as economic conditions dictate, with increased supplies as needed, made possible by the availability of equipment for their production, transportation, storage and utilization. As increased demands for LPG products come about, production should keep pace with or possibly exceed market demands. Increased discoveries of natural gas and gas-condensate fields and the development of catalytic-cracking operations, together with modern extraction and separation procedures, apparently assure the availability of increasing amounts of light hydrocarbon fractions for LPG products. In addition, these developments suggest production of sizable amounts of LPG in locations where heretofore a long haul by tank car was necessary.

Diversified opinions have been voiced regarding the magnitude of demands which may be made of LPG in its capacity as a chemical raw material on the return to normal times. Based upon present operations, which find butane-butene and isobutane as the key components for present chemical manufacture, when synthetic rubber and aviation fuel are included, there is a tendency to predict that butanes will be in such demand that a general shift to the lighter product, propane, will be necessary for the expansion of the LPG fuel industry. Rapidly changing conditions suggest that this supposition may not be entirely correct. In fact, some predict just the opposite; i.e., propane will be the key component for chemical manufacture and not butane. In analyzing this situation,[4] it must be pointed out that with the return to normal times the large quantities of butanes presently going into war material can be made available for peacetime uses. Too, we are now passing from an era of moderate thermal cracking into one in which intensified catalytic operations will predominate. Thus, where butane has been necessary to produce propylene in moderate thermal cracking, catalytic dehydrogenation will permit the use of propane as charging stock when the perfection of a satisfactory separation process is developed. In general, the present trend suggests

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The Roto Company
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Yours respectfully,

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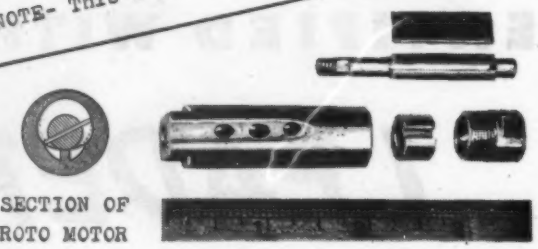
ACTUAL SIZE photo of Roto Junior cleaner with wire-flexible coupling and expanding brush.



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The Secret **of the power and endurance of the Roto Junior Tube Cleaner is its extreme simplicity of design and precision construction. It has only two moving parts, a shaft and a solid blade. Positive contact between the blade and the Roto-centric bore cylinder assure an undivided air stream and freedom from leakage. Its convenient size, speed and ease of operation, offer a marked contrast with old type, cumbersome external cleaners. Send for details.**

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DIVISION OF ELLIOTT COMPANY

that acetylene, ethylene and propylene will be the major components in tomorrow's chemical synthesis. The perfection of processes presently under investigation indicates the use of ethane and propane in ever-increasing quantities as raw materials for the production of these chemical components. Naturally, butane will be required as a raw material in many chemical operations, but this demand may not be as exhaustive as predicted by some. Therefore, the return to normal times should see a balanced demand for LPG products, allowing this industry to expand and progress in a reasonably stable and desirable fashion.

In a paper[5] presented before an industry association meeting in New Orleans, September, 1944, the author cautioned against the difficulties presently experienced by the warning, ". . . In other words, your immediate program should be to prepare for the worst." This advice still holds true and even after the present heating season is past, the LPG industry must continue a program which will enable it to meet its wartime responsibilities.

The difficulties now being encountered by the LPG industry to meet its responsibilities may even become more acute. Nevertheless, these sacrifices and determined efforts will not go unrewarded because these very experiences are creating an orderly, matured industry insuring a firm foundation upon which will be built tomorrow's modern LPG industry, an industry fully exploiting its unlimited opportunities and whose stature in a relatively short time will compare favorably with that of other large industries.

[1] Refer to glossary for definition of products and other notes.
[2] "Science in Natural Gas," by James E. Pew and Frank H. Dotterweich, Petroleum Administration for War.
[3] Mineral Market Report No. MMS 1204, United States Bureau of Mines, July 15, 1944.
[4] It is estimated that in 1944, LPG used as fuel will be less than 20 percent of the total LPG used for all purposes.
[5] "Will We Weather the Winter," by Paul K. Thompson, Petroleum Administration for War.

Russians Recover Vanadium from Asphalt

That certain fractions of petroleum, especially asphalt, may become a valuable source of vanadium, is indicated in a paper presented before the Russian Academy of Sciences last May. Vanadium is an important component of alloy steels for the manufacture of instruments and other special purposes.

A summary of the paper, which was presented by A. P. Vinogradov, has just reached this country and has been translated by J. G. Tolpin, editor of the U. O. P. Survey of Foreign Petroleum Literature. It discloses for the first time that a semi-commercial plant in producing ferrovanadium from asphalt derived from Ural crude, which may contain vanadium in quantities as high as 43 percent of the ash. The full text of the Vinogradov paper probably will be published in the near future.

It is known that asphalt from certain American crude oils, notably some produced in California and Oklahoma, contain considerable percentages of vanadium.

In 1940, the latest year for which figures are available, over 2,000,000 pounds of vanadium were produced in the United States and more than 2,500,000 were imported, principally from Peru. Demand has greatly increased during the war.

Natural Gas Production and Use At Record High in 1944

THE natural gas industry delivered to wartime plants, field operations, homes and commercial establishments a record volume of gas fuel during 1944. It is estimated that a total of 3,650,000,000,000 cubic feet of natural gas was consumed during the year. This represents an increase of approximately 246 billion cubic feet over 1943, a gain of 7 percent.

As usual, industrial use, including oil field and refining operations, accounted for most of the gas consumed. Preliminary figures indicate 2,845,000,000,000 cubic feet of natural gas were burned for these purposes, or more than two-thirds of the total. The gain in industrial consumption of natural gas totaled 175 million cubic feet, or 5 percent.

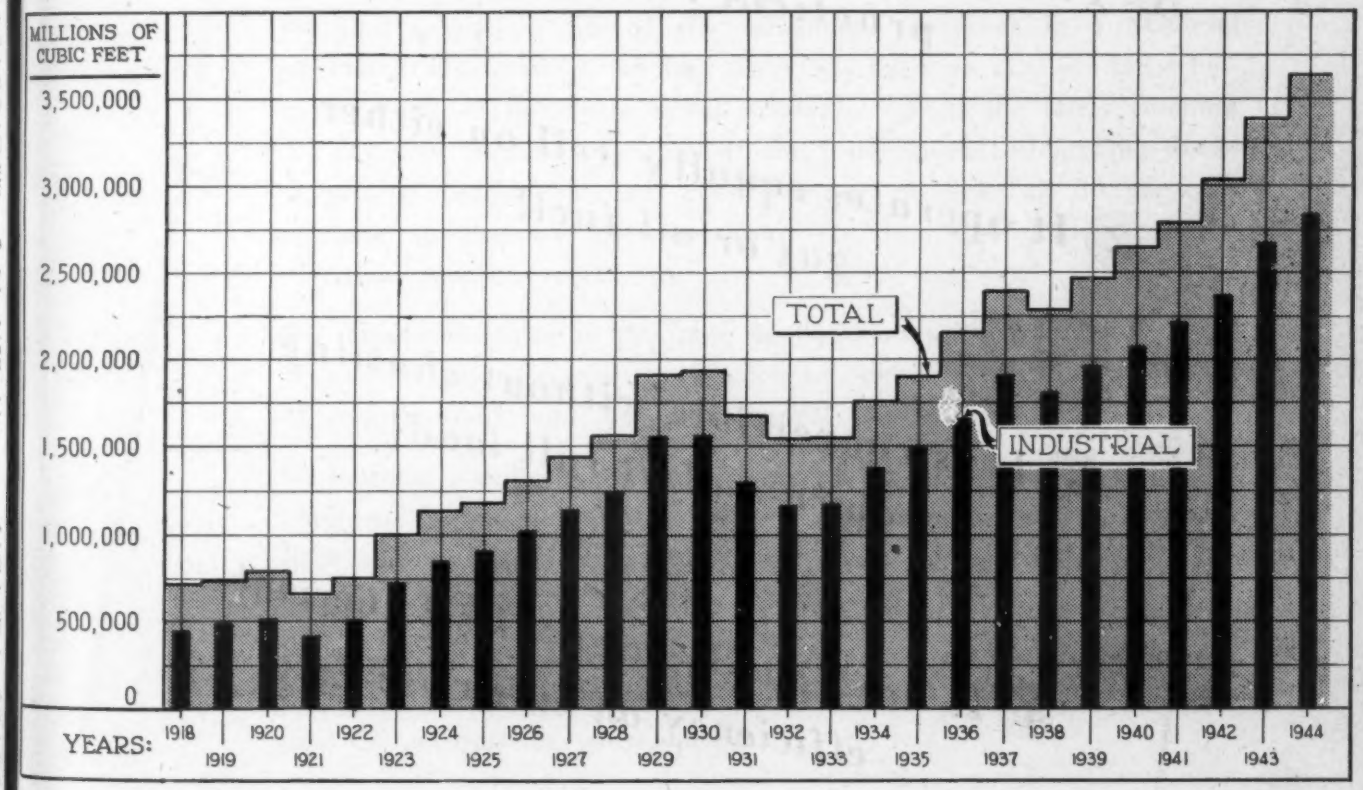
One of the outstanding natural gas developments of the year was the placing in operation of a 24-inch pipe line from Southwest Texas to West Virginia. It started operations in early November, and now is delivering over 200 million cubic feet of gas per day into the highly industrialized Appalachian area, relieving a threatened gas shortage in that region.

Several pipe lines are being projected from West Texas or the Texas Panhandle to California to supplement the natural gas supply in that state. One of these lines may be built during 1945, if WPB gives approval for material.

In addition to expansion of facilities, important strides have been made in the future use of natural gas as a chemical agent.

United States Annual Natural Gas Consumption Since 1918

(Millions of Cubic Feet)



YEAR	CONSUMPTION [1] Domestic and Commercial	Industrial	Total	Production Marketed
1918	271,000	450,000	721,000	721,000
1919	255,743	490,173	745,916	745,916
1920	286,001	512,209	798,210	798,210
1921	248,334	413,718	662,052	662,052
1922	254,413	508,133	762,546	762,546
1923	277,050	729,917	1,006,967	1,006,967
1924	285,152	856,330	1,141,482	1,141,482
1925	272,146	916,293	1,188,439	1,188,439
1926	289,175	1,023,678	1,312,853	1,303,019
1927	296,036	1,149,208	1,445,244	1,455,428
1928	320,877	1,247,102	1,567,979	1,568,139
1929	359,853	1,557,598	1,917,451	1,917,693
1930	295,700 80,707	1,565,237	1,941,644	1,943,421

YEAR	CONSUMPTION Domestic	Commercial	Industrial	Total	Production Marketed
1931	294,406	86,491	1,303,322	1,684,219	1,686,436
1932	298,520	87,367	1,168,448	1,554,335	1,555,490
1933	283,197	85,577	1,184,625	1,553,399	1,555,474
1934	288,236	91,261	1,385,491	1,764,988	1,770,721
1935	313,498	100,187	1,496,216	1,909,901	1,915,595
1936	343,346	111,623	1,665,549	2,160,518	2,167,802
1937	371,844	117,390	1,913,807	2,403,041	2,407,620
1938	367,772	114,296	1,812,029	2,294,097	2,295,562
1939	391,153	118,834	1,963,778	2,473,765	2,476,756
1940	443,646	134,644	2,076,369	2,654,659	2,660,222
1941	442,057	144,844	2,218,281	2,805,192	2,812,658
1942	498,537	183,603	2,362,633	3,044,773	3,053,475
1943	529,444	204,793	2,669,242	3,403,479	3,414,689
1944	570,000	225,000	2,845,000	3,640,000	3,650,000

[1] Breakdown between domestic and commercial use not available prior to 1930. Source: U. S. Bureau of Mines; except for latest year which is based on statistics of American Gas Association revised to Bureau basis by adding estimated consumption for oil field operations and carbon black purposes.

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1. *The gas-fueled diesel is now a practical reality!*

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4. *It has equally high diesel thermal efficiency on either fuel!*

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Development in Years!

EVER since 1928, Cooper-Bessemer has been experimenting to perfect a means of using gas as a practical diesel fuel and to permit instantaneous change-over from fuel oil to gas and vice versa. It can now be announced that these efforts have been completely successful — a truly revolutionary accomplishment.

Without exception, all of the advantages inherent in full diesel operation are retained. In fact there has been no modification whatever of the characteristic diesel principles. Thus the fairly common 35 per cent thermal efficiency of the conventional oil-burning diesel is just as readily reached when burning gas — a full 30 per cent increase in thermal efficiency over the best gas engines of the electrical ignition type.

An important factor in this new development is the admission of gas at normal pressure, assuring customary diesel reliability, avoidance of complications, and low maintenance.

Of extreme significance in many services, instantaneous convertibility from one fuel to the other is in itself an outstanding accomplishment. It is as simple as opening one valve and closing another while the engine is running at full load.

Engineers and operating officials in many fields will instantly recognize the tremendous economies and advantages made possible by this new Cooper-Bessemer development.

Corporation Mount Vernon, Ohio — Grove City, Pa.

Natural Gasoline Output Passes 100 Million Barrels in 1944

STIMULATED by increasing war demands, United States production of natural gasoline and allied products soared to an all-time high of 102,000,000 barrels in 1944.

Answering the need for more aviation gasoline, synthetic rubber and basically kindred goods to feed war machines, production went up in a rapid spiral not fully described by the year's total output. From a daily average of 252,000 barrels in January, production moved up to approximately 300,000 barrels daily in December, indicating an increase for 1945 that will compare with the 13,821,000-barrel gain made in 1944.

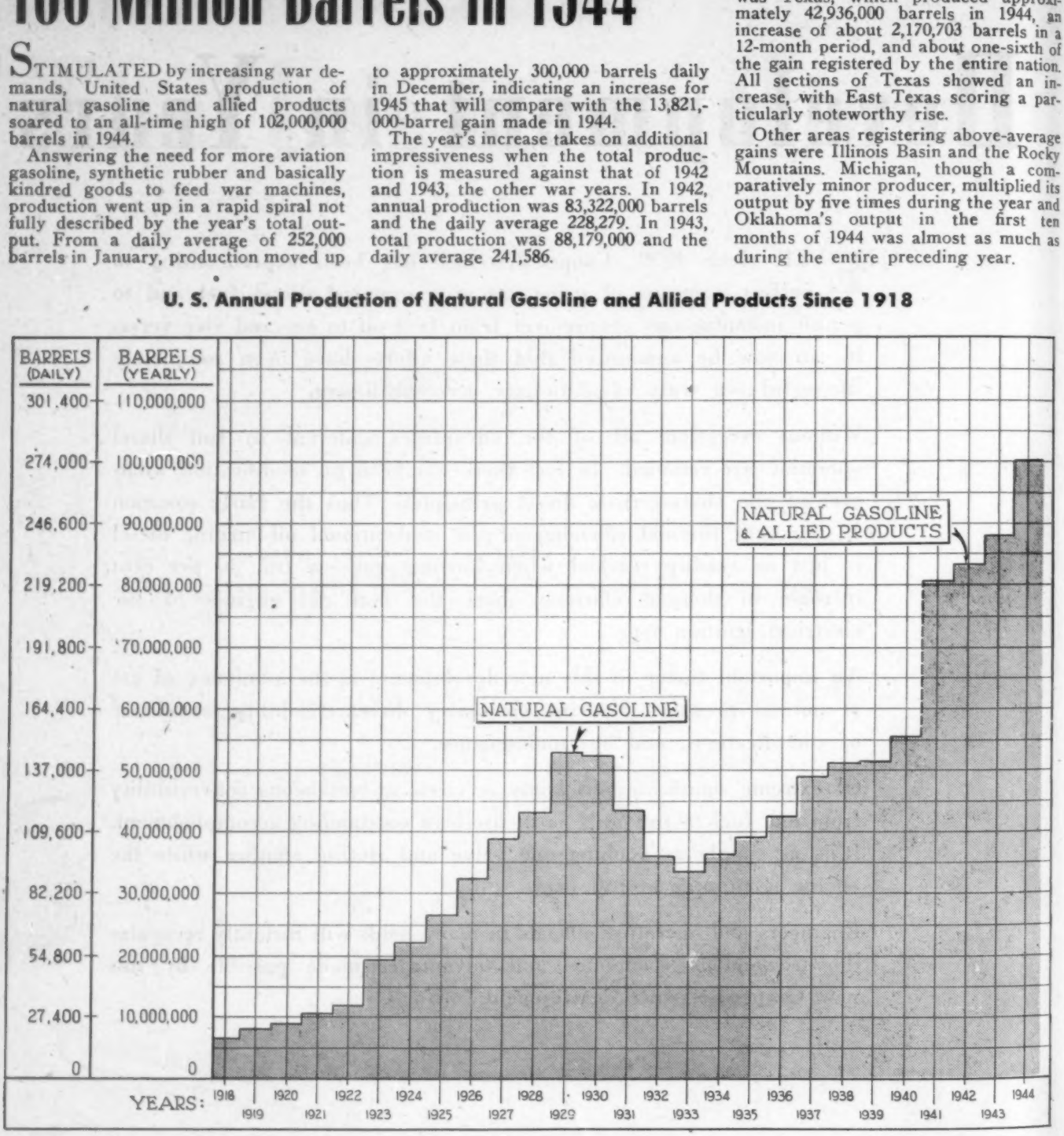
The year's increase takes on additional impressiveness when the total production is measured against that of 1942 and 1943, the other war years. In 1942, annual production was 83,322,000 barrels and the daily average 228,279. In 1943, total production was 88,179,000 and the daily average 241,586.

Increased plant capacity and war-time urgency resulted in a gain of approximately 50,000 barrels daily between December, 1943, and December, 1944, and a gain of almost 65,000 barrels daily between June, 1943, and December, 1944.

Locale of the greatest gain in 1944 was Texas, which produced approximately 42,936,000 barrels in 1944, an increase of about 2,170,703 barrels in a 12-month period, and about one-sixth of the gain registered by the entire nation. All sections of Texas showed an increase, with East Texas scoring a particularly noteworthy rise.

Other areas registering above-average gains were Illinois Basin and the Rocky Mountains. Michigan, though a comparatively minor producer, multiplied its output by five times during the year and Oklahoma's output in the first ten months of 1944 was almost as much as during the entire preceding year.

U. S. Annual Production of Natural Gasoline and Allied Products Since 1918



(All Figures in Barrels)

YEAR	Annual Production	Daily Average	YEAR	Annual Production	Daily Average	YEAR	Annual Production	Daily Average	YEAR	Annual Production	Daily Average
1918	6,727,000	18,430	1925	26,845,000	73,547	1932	36,281,000	99,400	1939	51,650,000	141,507
1919	8,370,000	22,931	1926	32,455,000	88,917	1933	33,810,000	92,630	1940	55,700,000	152,502
1920	9,161,000	25,098	1927	39,075,000	107,054	1934	36,556,000	100,153	(*) Natural Gasoline and Allied Prod.		
1921	10,713,000	29,350	1928	43,191,000	118,331	1935	39,333,000	107,761	1941	80,855,000	221,520
1922	12,044,000	32,997	1929	53,183,000	145,706	1936	42,770,000	117,178	1942	83,322,000	228,279
1923	19,434,000	53,243	1930	52,631,000	144,194	1937	49,177,000	134,731	1943	88,179,000	241,586
1924	22,235,000	60,197	1931	43,617,000	119,498	1938	51,347,000	140,676	1944	102,000,000	279,452

Source:—Bureau of Mines, except for latest year, which is estimated.
* Bureau began a new series covering 1941 and subsequent years which includes some cycle condensate.

Report Progress on New Version of World Oil Pact

Harold L. Ickes has had added to his myriad titles and duties that of acting chairman of a committee of cabinet members appointed by the President to reconcile differences between the American oil industry and the government over the Anglo-American petroleum agreement. Much progress has been made to this end, Ickes announced on January 24 after a three-day discussion. The discussion was informal but announcement of its results was a formal release through the Office of War Information. In it was reviewed the industry's objection to the wording of the agreement first presented which it considered "might be construed prejudicially to United States domestic operations."

"Representatives of the government did not consider that the agreement embraced the dangers which industry spokesmen had believed that they saw therein," Ickes said. "They considered it a sound document, protective of the public interest of both nations, beneficial to the oil industry, and conducive to the fair and orderly conduct of the international petroleum trade. They expressed willingness, nevertheless, to consider suggestions for such revisions as might reasure the industry, provided that the purpose of the agreement was preserved."

To this gracious acquiescence to their right to be heard, representatives of the industry acting through the Petroleum Industry War Council, responded by presenting its objections and a proposed new draft.

"Although not all of the industry's suggestions were acceptable to the government," Ickes said, "a study of them showed that as to the content of the original document there was no substantial difference upon basic considerations. Government and industry were agreed that the proposed International Petroleum Commission should be a purely advisory and consultative body; that acceptance of its suggestions should be elective with each government; and that nothing in the agreement should be interpretable as vesting in the federal government any powers now residing in the states."

The original agreement between representative of the American and British governments was referred to the United States Senate for ratification, and was withdrawn when opposition from petroleum and other business sources indicated the probability that it might be rejected by that body.

API Meeting Is Scheduled for Fall

The American Petroleum Institute has announced that the 1945 annual meeting is tentatively scheduled for November, at the Stevens Hotel, Chicago, the exact date of the meeting to be set later.

Postponement of the meeting from 1944 provides automatically for continuation of membership in committees, thereby giving incumbent members a two-year term instead of the customary one-year term.

Pending the meeting, all committees in the division or production will continue to function. It is likely that meetings may be held with some of the committees where deemed advisable by the chairman.

All spring district meetings with exception of California, have been cancelled.

Officers of the California district are in favor of going ahead with their spring meeting as it would not entail a burden on transportation.

James Named Director Of Research Council

W. S. James, chief engineer of Studebaker Corporation, was the only new member of the board of directors elected at the annual meeting of Cooperative Research Council. He replaces J. B. Macauley, Jr., who declined reelection. Reelected directors include D. P. Barnard, Standard Oil Company (Indiana); G. H. B. Davis, Standard Oil Development Company; J. F. M. Taylor, Shell Oil Company; B. B. Blackman, Autocar Company, and C. G. A. Rosen, Caterpillar Tractor Company.

The council is sponsored by American Petroleum Institute and American Society of Automotive Engineers.

Military Takes Tankers, Demands More Oil

Military demands have made necessary removal of more tankers serving the East Coast of the United States, to further complicate supplying that area. More of the burden of transport goes back on the railroads, in face of a shortage of tank cars.

Increased demand by the armed forces for aviation fuel has made it necessary for Petroleum Administration for War to revise upward its production program. This may involve construction of more refineries. To the present demands have been met with the construction program which is all but completed, but Army and Navy schedules for coming months are above capacity of existing plants. Some increase is in prospect by removing bottlenecks and improving methods in existing plants, but construction of additional facilities is seen as necessary and plans are being laid to that end. Already three plants have been authorized, and PAW is making a survey to determine where the manpower situation makes it most advisable to build more refineries.

Along with more oil and more transportation, the war is demanding more steel from the sources which would supply materials for the new plants. It is indicated that PAW will not be in position to even recommend material be made available for other than most essential projects. Men, machinery and materials which make pipe also are used to make shells, and demand for the latter is so edging into the pipe supply that production and exploration drilling may be forced short of proposed schedules, to the embarrassment of securing sufficient crude oil.

Railroads are being called upon to resume more of the load of supplying oil to the East in face of many difficulties. Before the government pipe lines were built the railroads moved 71 percent of the oil going into the East, but with the lines operating this load dropped to a volume of only about 16 percent. Many of the cars used in the peak of the rail movement now are in repair shops, some have been diverted to other uses, and to moving a growing volume to the West Coast. Many

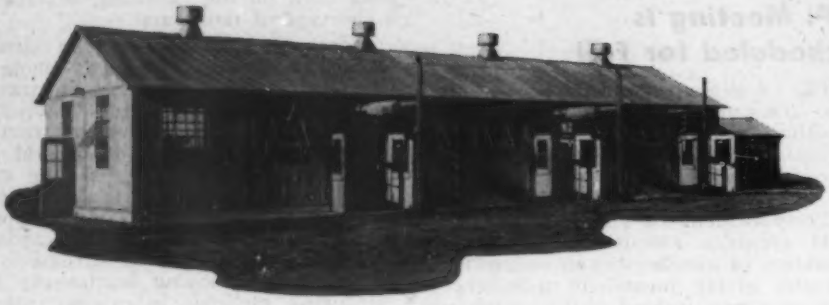
Crude Oil Runs to Stills, Production of Refined Products, and Stocks for the Four-Week Period Ending January 20, 1945

(Figures, in thousands of barrels of 42 U. S. gallons each, based on reports of American Petroleum Institute. Production and stocks include reported totals plus estimated amounts to make these figures on a Bureau of Mines basis)

DISTRICT	Capacity Percent Reporting	Crude Runs to Stills: Daily Average	Crude Runs to Stills: Percent Operating	Production: Gasoline*	Production: Kerosine	Production: Gasoil and Dist. Fuel Oil	Production: Residual Fuel Oil	Stocks at Refineries Terminals and in Pipe Lines: Finished and Unfinished Gasoline	Stocks at Refineries Terminals and in Pipe Lines: Kerosine	Stocks at Refineries Terminals and in Pipe Lines: Gasoil and Dist. Fuel Oil	Stocks at Refineries Terminals and in Pipe Lines: Residual Fuel Oil	Crude Oil: Daily Average Production	Crude Oil: Stocks†
East Coast	100.0	720	98.8	7,149	703	3,469	6,533	12,354	3,366	7,858	5,215	.....	.....
Appalachian District 1	83.9	96	74.2	1,143	230	284	395	2,652	493	362	288	.....	.....
Appalachian District 2	87.2	57	120.2	771	59	182	372	1,699	61	216	249	.....	.....
Illinois, Indiana, Kentucky	85.2	765	92.9	11,495	1,055	2,635	4,522	20,098	2,065	5,290	2,774	.....	.....
Oklahoma, Kansas, Missouri	80.2	391	93.3	5,614	578	1,667	2,002	8,759	566	1,970	1,284	.....	.....
Inland Texas	66.9	238	85.5	3,720	367	519	1,835	2,823	160	381	656	.....	.....
Texas Gulf Coast	90.5	1,126	96.7	13,658	1,638	5,272	7,456	15,254	1,246	6,817	9,147	.....	.....
Louisiana Gulf Coast	95.5	246	101.5	3,304	860	1,010	1,202	4,256	792	1,368	1,359	.....	.....
North Louisiana, Arkansas	68.0	81	77.9	872	194	262	478	2,838	149	781	263	.....	.....
Rocky Mountain District 1	17.0	11	82.8	143	16	30	120	81	10	20	28	.....	.....
Rocky Mountain District 2	58.3	116	81.9	1,524	78	256	899	1,731	97	346	526	.....	.....
California	89.9	831	101.7	9,114	178	2,198	10,509	16,163	440	9,632	30,765	.....	.....
Total U. S. January 20, 1945	87.2	4,678	95.3	58,507	5,956	17,784	36,323	88,708	9,445	35,041	52,554	4,734	221,114‡
Total U. S. December 30, 1944	87.2	4,642	94.6	.....	.....	.....	.....	86,614	11,296	39,495	57,430	4,705	222,998
Total U. S. January 22, 1944	.....	4,372	.....	.....	.....	.....	.....	79,444	8,657	38,112	53,121	4,389	238,148

* Includes natural gasoline blended at refineries. † Bureau of Mines. ‡ January 13, 1945.

BRADEN
SECTIONAL STEEL BUILDINGS



Some of These Days—

Your plant and buildings will probably require extensive re-designing for the competitive production of peace time motor fuels. When that time comes will you be able to salvage your buildings?

Braden Buildings are constructed with prefabricated Sectional Steel Panel Sections. This permits utmost freedom when re-designing a plant to meet new process requirements, and every panel retains its original function.

SALVAGE IS PRACTICALLY 100 PER CENT!

Our Engineers will be glad to assist in designing the new plant.

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BRADEN *Steel* BUILDINGS

BRADEN STEEL CORPORATION

1007 East Admiral Blvd. Tulsa 3, Oklahoma

Subsidiary of MOORLANE COMPANY

Branch Offices: Houston and Dallas, Texas and Cleveland, Miss.

Representatives: Kansas City, Mo., Amarillo, Tex., Wichita, Kan., Odessa, Texas., Oklahoma City, Okla.

Export Agent: Russell D. Heath, 50 Church St., New York, N. Y.

cars are being used to shuttle high-octane gasoline components between plants, and some are required for short-haul service where trucks which formerly served are out of tires.

Transport officials are making efforts to improve efficiency of tank-car movement, and heavy demurrage charges have been imposed to halt delays in unloading. Weather conditions in the northern area currently are causing delay of cars en route at a time when fuel consumption is high, and prospects for an acute situation in the spring are mounting.

Budget Gives More Funds For Synthetic Fuel Study

A fund of $13,000,000, compared with $5,000,000 this year, is provided for the United States Bureau of Mines' investigation of liquid fuels from coal, shale and agricultural products, was among the items proposed by President Roosevelt in his annual budget message to Congress January 9. The message indicated no hope that government expenditures after the war will return to prewar levels, and forecast that any drop during 1945 in war expenditures would be accompanied by a drop in national income and tax revenue. It made no detailed estimates of funds needed by the armed forces or the various war agencies, including PAW, WPB, or OPA; these figures are to come in a special message in the spring, and will reflect changes which then may have occurred in the military situation.

In addition to the increased amount provided for the fuels research program, set up as a five-year project last year, estimates for the permanent agencies dealing with oil included $209,000 for the petroleum conservation division of the Interior Department, an increase of $9,000; oil and gas investigations by the Bureau of Mines, $583,000, a decrease from $657,640 for the current year, and $80,000 for investigations in connection with helium.

East Indies Interests Fear American Synthetic Rubber

Representatives of the United States and Dutch governments met in Washington late in January to discuss rubber, and particularly the role to be played by synthetic rubber after the war.

Discussion centered around the synthetic industry and the extent to which it will be continued after the war.

From such estimates as can be made, the British and Dutch plantations are not likely to produce as much as a half million tons of rubber during the first year after re-occupation of the islands now held by the Japanese, and world rubber requirements will call for more than a million tons of synthetic. In the following year, however, it is estimated that the position will be reversed, and more than a million tons of natural rubber will be available with requirements for about a half million tons of synthetic. Thereafter, with plantation production at a capacity of 1,600,000 tons, approximately world requirements, any synthetic made would come into direct competition with natural rubber.

The eventual disposition of the synthetic-rubber industry, therefore, is seen as a major problem for the tri-partite experts, accentuated by the demands in this country for retention of sufficient synthetic facilities to insure against our

Our Experience Includes:

**Alkylation,
Polymerization
and Isomerization**

**Reforming,
Thermal Cracking
and
Catalytic Cracking**

**Skimming,
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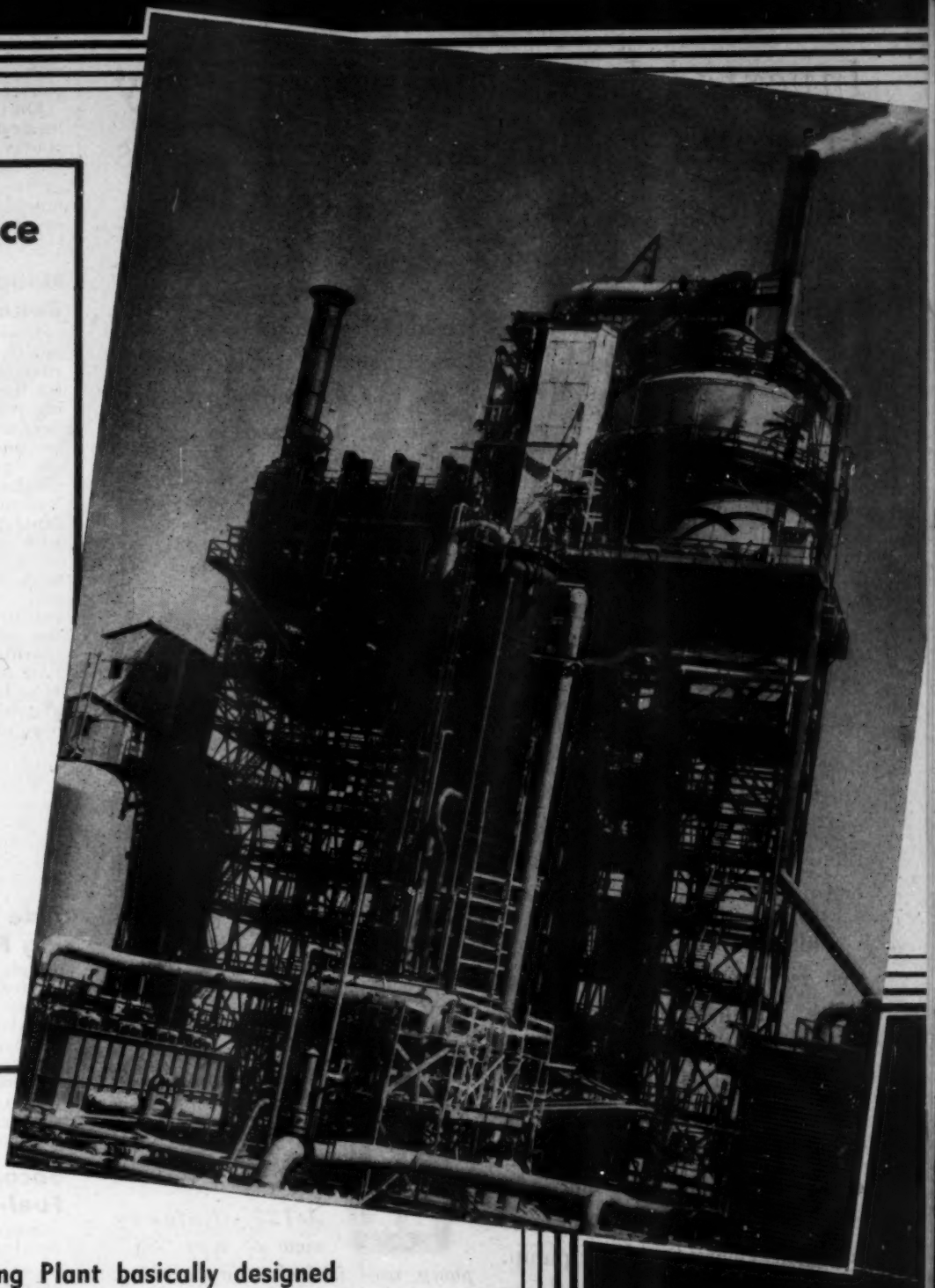
and
Sulphur Removal,
Treating, Utilities
and Auxiliaries**

**Crude Stabilization,
Crude Desalting,
Gas Compression
and Absorption,
Gasoline Stabilization,
Recycling and
Gas Lift**



Fluid Catalytic Cracking Plant basically designed by Universal Oil Products Company. We engineered and constructed the first unit of this type to go on stream.

Engineering and Construction Division

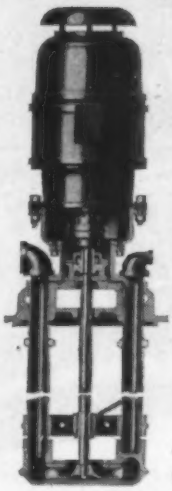
JONES & LAUGHLIN SUPPLY COMPANY

TULSA, OKLAHOMA

Inverted Inlet Pump Efficiently Handles De-coking Operations

The problem of pumping the highly abrasive coke-laden water from hydraulic de-coking of vertical chambers has been solved by one midwestern refiner with Amsco-Nagle type "SW" vertical shaft wet pit inverted inlet pumps, fitted with manganese steel water end parts.

This pump has many features that recommend it for de-coking units. The inverted inlet eliminates gas or air binding and causes hydraulic thrust to counterbalance the weight of moving parts. Wide impeller clearances permit the passage of sizable pieces of coke, thus increasing the material handling efficiency of the pump. Steady and intermediate sleeve bearings are supported in split yokes and may be replaced without dismantling the pump. The tubular structural members serve a dual purpose. The one on the left in the cutaway view serves as a duct for lubricants and the one on the right serves as the discharge pipe. Manganese steel water end parts are used to combat the abrasive effects of the coke. Other materials are available to meet various corrosive or abrasive conditions in both horizontal and vertical type Amsco-Nagle pumps.



P163N — A 5" type "SW", frame 14 inverted inlet Amsco-Nagle pump, similar to those used in de-coking operations. Note fittings for lubricating steady and intermediate bearings from floor level.

A-125 — Cutaway view of type "SW" pump, used in hydraulic de-coking. Note the inverted inlet.

The many features of these soundly engineered pumps are described in Bulletin 940, sent on request.

Amsco
AMERICAN MANGANESE STEEL DIVISION
Chicago Heights, Illinois
FOUNDRIES AT CHICAGO HEIGHTS, ILL.; NEW CASTLE, DEL.; DENVER, COLO.; OAKLAND, CALIF.; LOS ANGELES, CALIF.; ST. LOUIS, MO.
OFFICES IN PRINCIPAL CITIES

AMERICAN Brake Shoe COMPANY

ever again being entirely cut off from rubber supplies.

On the other hand, British and Dutch interests see a potential threat to their rubber markets if synthetic production is continued, fearing that as the industry gains experience and develops new techniques the production cost will be lowered to a point where it may cut under the prices of natural rubber.

Houdry Announces Running Royalty Plan

Houdry Process Corporation, Wilmington, Delaware, has announced a running royalty financial arrangement for licensees of Houdry catalytic cracking processes. The plan is applicable to licenses for both the Houdry fixed-bed and the Thermofor Catalytic Cracking processes, and covers catalytic cracking operations generally, regardless of end products. The terms are 5 cents per barrel of fresh feed charge, with no additional cost for recycling or treating for aviation gasoline production. The paid-up licensing plan is still available. "The new plan," it was explained, "is designed especially to aid the small refiners and assist them in sharing the expanded markets for catalytic motor fuel and specialty products. It is backed by the engineering service and laboratory facilities of the Houdry organization, which is serving 59 catalytic cracking plants throughout the country."

Technical representatives of refiners using the Houdry fixed-bed process met at St. Louis on January 18-19 for a general discussion of the process and methods of increasing production of aviation gasoline.

Tide Water Operating Big Fluid Unit

Tide Water Associated Oil Company started operation of the world's largest single fluid catalytic cracking unit at its Avon, California, refinery late in December. The unit has a charging capacity of 18,000 barrels of gasoil per day. The unit was designed and built by C. F. Braun & Company with engineering assistance from Universal Oil Products Company.

Socony-Vacuum Plans Fuel-Oil Laboratory

Socony-Vacuum Oil Company plans construction in Brooklyn, New York, of a laboratory for studying performance of fuel oils in commercial burners, as a basis for adapting refining processes to production of satisfactory fuels for industrial and domestic use. Provision also will be made for salesmen to give consumers in the area instruction on proper handling of the fuel.

Name Committee to Operate Standard's Louisiana Unit

M. W. Boyer, general manager of Baton Rouge refinery, and a vice president of Standard Oil Company of New Jersey, has been named chairman of the "management committee" which assumes virtually the responsibilities of the former board of directors of Standard Oil Company of Louisiana. This setup is in furtherance of absorption by Standard Oil Company of New Jersey of the corporate identity of the Louisiana company, which now is designated Louisiana Division. Other members of the committee are F. P. Hagaman, con-

Aerocat*

CRACKING CATALYST

Made by Cyanamid

Cyanamid is now manufacturing at Fort Worth, Texas, *AEROCAT** Synthetic Fluid Cracking Catalyst Grades F and G. These grades are made to specifications developed by Universal Oil Products Company. The strategic location of Cyanamid's Synthetic Fluid Cracking Catalyst production assures prompt, economical delivery of *AEROCAT* to the major part of the refining industry.

Cyanamid's long experience in catalyst manufacture, extensive technical facilities combined with modern large scale production capacity assure refiners of a reliable, uniform quality source of supply.

Also, in order to assist refiners to get the proper grade of catalyst to meet the conditions prevailing in each plant, the Cyanamid technical service staff is available for consultation.

U. O. P. TYPE SYNTHETIC
Fluid
CRACKING CATALYST

**Trade-mark of American Cyanamid & Chemical Corporation denoting cracking catalyst of its manufacture.*

When Performance Counts... Call on Cyanamid

American CYANAMID & Chemical Corporation

(A Unit of American Cyanamid Company)

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troller of Louisiana Division, vice chairman; S. E. Kidd, assistant secretary and assistant treasurer of Standard Oil Company of New Jersey, secretary; H. J. Voorhies, assistant general manager of Baton Rouge refinery; T. M. Gordon, manager of Louisiana marketing division; Cecil Morgan, associate general attorney; W. P. Reymond, Jr., manager of employe relations at Baton Rouge refinery, and C. H. Whitman of Shreveport, manager of crude-oil purchases.

M. J. Rathbone, former president of Standard Oil Company of Louisiana, was elected president of Standard Oil Company of New Jersey several months ago. Consolidation of the two companies was effective on January 1, 1945.

Barbour Heads Allied Materials Corporation

C. W. Barbour has been made president of Allied Materials Corporation, Oklahoma City, in a reorganization attending resignation of T. A. Nicholson, whose stock was acquired by the company. Barbour has been executive vice president in charge of operations. Bert Brooks succeeds as vice president.

Wheeldon to Direct Shamrock Operations

Harry Wheeldon, who has been in charge of Shamrock Oil & Gas Corporation's plant near Dumas, Texas, since joining the company in 1943, has been elected a vice president of the corporation, and now will be in charge of all operations, including refining, production and exploration.

Opens Patent-Law Office

Peter J. Gaylor has resigned his connection with Standard Oil Development Company to open law offices at 790 Broad Street, Newark 2, New Jersey. He will specialize in patent law, trade marks and copyrights, and also will publish a weekly service covering new trends and developments in technology.

Joins Gas Institute

N. W. Muller has resigned as design engineer at Whiting refinery for Standard Oil Company (Indiana) to join the staff of Institute of Gas Technology, Chicago. He is to work on development of applications of the institute's new pulverizer.

Ohio Standard Celebrates Seventy-Fifth Anniversary

Incorporated on January 10, 1870, by John D. Rockefeller and associates at Cleveland, as the original "The Standard Oil Company," The Standard Oil Company (Ohio) on the anniversary of that date this year celebrated its seventy-fifth year in business. Company employes were gathered at Cleveland's Public Auditorium for an hour of entertainment which was broadcast over 22 stations, and tied in with smaller gatherings in 12 other Ohio cities. The occasion also was noted in other states where the company has production and pipe-line activities.

A souvenir of the celebration was a 64-page pictorial history of the company's development, divided into periods of The Lamp, The Automobile, and The Airplane. Refinery pictures in this brochure range from the original installations to the company's recently

Machines That Turn Out

Precision-Made Wire Cloth

NEWARK for ACCURACY

IF WOVEN WIRE is to be used for screening there's every reason to insist upon accurately made cloth. If cloth is not precise in its mesh or space, of what use is it as screening medium?

NEWARK FOR ACCURACY is not an empty phrase. From the machines in our modern factory, comes wire cloth that cannot be surpassed for its accuracy in every detail—wire gauge, mesh, space, crimping.

Quality is evident throughout the entire range of NEWARK Wire Cloth.

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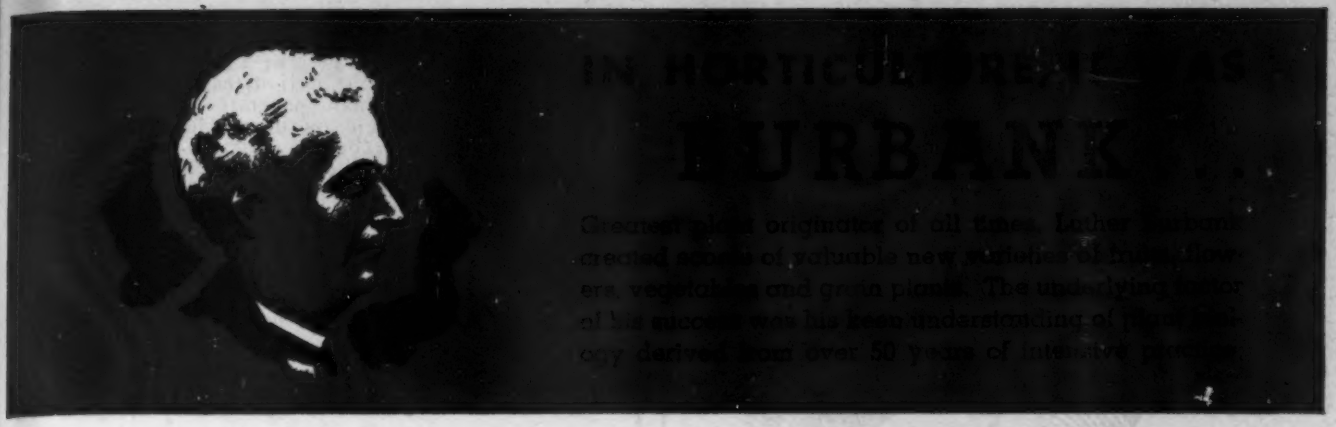


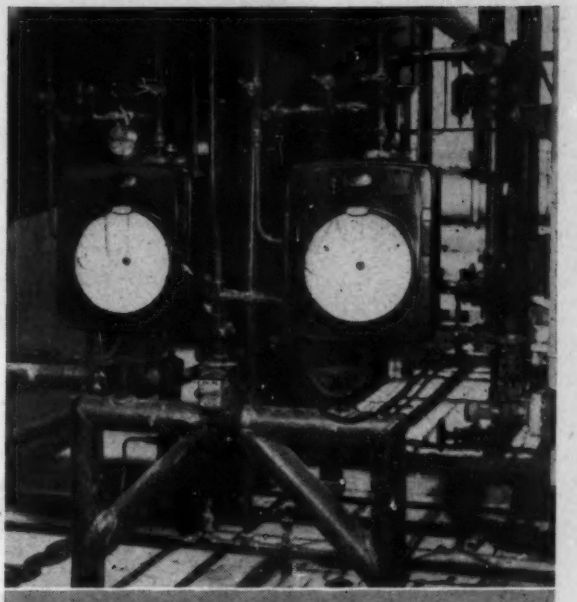
IN INSTRUMENTATION IT'S FOXBORO!

In process control, as in any other science, leadership can derive only from more-thorough understanding of the fundamental principles and greater familiarity with their application.

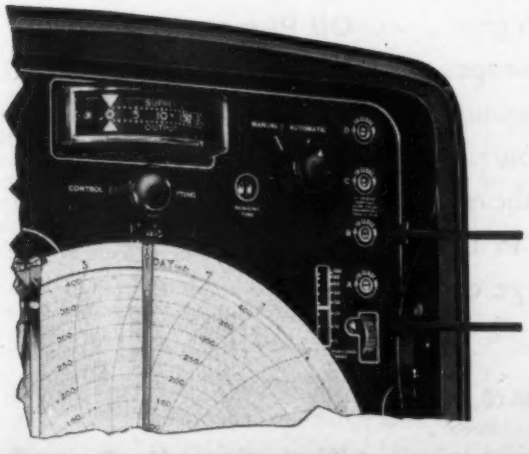
For more than 30 years, Foxboro engineers have concentrated on creating new instruments to measure, record and control process conditions. Seeking perfection, they have set new standards in instrument performance . . . standards never even approached by previous instruments!

The Foxboro Stabilog Controller with HYPER-RESET is a perfect example of this ability plus experience. This instrument provides both automatic reset and an exclusive, selective rate-sensing action. It "feels" the rate of disturbance change the instant it starts, and applies corrective action of the exact magnitude required. Recovery is often effected in ¼ the usual time, with the amount of upset held to a minimum.

To help you determine how the HYPER-RESET Stabilog Controller can improve your production, our engineers have prepared illustrated Bulletin A330. Write for your copy. **The Foxboro Company, 74 Neponset Ave., Foxboro, Mass., U. S. A.**



Two of the Foxboro Stabilog Controllers that help make the Cities Service Lake Charles Refinery "the world's most modern petroleum plant."



THE ONLY CONTROLLER WITH ONLY 1 ADJUSTMENT FOR BOTH RESET AND RATE-SENSITIVE FUNCTIONS

Foxboro's Hyper-Reset Stabilog Controller simplifies normal adjustment by combining the reset and rate-sensitive functions. Hence, just 1 adjustment gives optimum unit process control.

1. **Hyper-Reset** combines the reset and rate-sensitive functions. Just one adjustment is needed to establish both settings.

2. **Proportional Band** is adjusted between zero and 100 per cent simply by turning a knurled knob. A lock screw protects against any later unauthorized changes in adjustment.

FOXBORO Stabilog Control

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A SMALL SAMPLE
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A 1000 lb. carbon moly header . . . for use on a high pressure line. Small sample, indeed, of the steady stream of industrial piping fabrication that flows through the Associated shops in an endless continuity.

The quantity and the quality of work handled here indicate the exceptional degree of ability available to cope with whatever problem your piping requirements pose . . . Let Associated assume the responsibilities inherent in all fabrication jobs, large or small—for you.

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ASSOCIATED *Progressive* **PIPING**

completed plants for producing aviation fuel.

The present The Standard Oil Company (Ohio) dates its separate and individual corporate existence from the dissolution decree in 1911. Started as a refining and marketing unit, for some years its marketing activity outweighed the refining end. Since 1928, when W. T. Holiday became president, the company has branched out into producing crude oil and transporting it by pipe line and barge, at the same time continuing its aggressiveness in marketing and in improvement of processes and expansion of facilities for refining.

Sun Oil Company Improves Refinery Safety Record

Sun Oil Company reports a decline of 16 percent in accidents at its Marcus Hook refinery since start of a safety campaign last June. During the period man hours worked increased 1,382,063 (29 percent) over the previous six months, while 1871 new workers were added to the payroll, and 1456 left that employment. There were five fatalities during 1944, three before and two during the campaign. In spite of these tough breaks, the company feels the campaign has shown definite results, and will be continued during 1945.

W. J. Noctor, safety engineer at Marcus Hook, and N. L. Soutar, manager of plant protection at Toledo refinery, are the safety campaign directors. A. W. MacMurtrie and G. N. Closs, refinery managers at Marcus Hook and Toledo, respectively, are chairmen of the executive committees in direct charge of the drives. Large committees have been appointed from among workers. These men are responsible for seeing that workers avoid unsafe practices and the unsafe equipment is not used. Their work is supplemented by regular inspections by the safety department. Posters and sign boards are used, and there have been several contests on suggestions, slogans and posters. Units within each refinery compete for excellence of safety records, and their standings are recorded by flags which go up or down according to the records.

Oil Personnel High in Deferred Draft List

Petroleum refining, production of natural gasoline and liquefied petroleum gases, and most operations in the production and transportation of oil and gas were rated "critical" in revision January 16 by the War Manpower Commission of its list of occupations necessary for prosecution of the war. This revised list is for guidance of draft boards in the induction of 900,000 men into the armed forces during the first half of the year. This means that probably few, if any, men in the 26-29 age group now employed in the oil industry will be affected by the stepping up of military inductions.

Given Security Award

Standard Oil Company (Indiana)'s Wood River refinery has been given the National Security Award for its "superior standard of protection and security." The award was made by United States Office of Civilian Defense, in praise of both management and workers.

THEY CALL 'EM JEEPS

BECAUSE THEY'RE SMALL, BUT POWERFUL, AND GO ANYWHERE

For a small, tough, hard-working turbine that will go anywhere and do all you expect of it . . . get a Coppus "Blue Ribbon" Steam Turbine.

Coppus Steam Turbines come in six frame sizes from 150 HP down to fractional—so you can match more closely your job requirements. Each smaller size is priced correspondingly less, so by selecting "horsepower" instead of "elephant power" you save on investment and installation cost.

Many well-known manufacturers install Coppus "Blue Ribbon" Steam Turbines on original equipment. They know Coppus quality will protect the reputation of their own products. The Coppus Turbine is also being used on many U. S. Destroyer Escorts, all Casablanca class aircraft carriers and 90% of all Landing Ship Docks.

Like all Coppus "Blue Ribbon" products (blowers, ventilators, gas burners, etc.), the Coppus Steam Turbine is a precision-made product, with accuracy controlled by Johansson size blocks. Every turbine is dynamometer-tested before shipment.

More than 85% of all orders since 1937 have been repeat orders.

Write for Bulletin 135-9. Coppus Engineering Corporation, 282 Park Avenue, Worcester 2, Mass. Sales offices in THOMAS' REGISTER. Other Coppus "Blue Ribbon" Products in SWEET'S, CHEMICAL ENGINEERING CATALOG, REFINERY CATALOG.

ANOTHER

COPPUS

"BLUE RIBBON" PRODUCT

Back on Stream *in less time*

Throughput losses due to unnecessarily long downtime of stills and similar tubular equipment for cleaning can be eliminated—with Wilson Tube Cleaners.

Heavy coke deposits in still tubes can be removed quickly and easily with a Wilson E.P. motor-operated cleaner. The extra power of this motor prevents stalling even when the heaviest deposits are encountered. Air consumption is reduced to a minimum by the exclusive automatic valving of the driving air, and its special six-blade light-blade construction assures a smooth flow of power plus high torque.

Thomas C. Wilson, Inc. maintains a large engineering staff to help you solve your tube cleaning problems. A copy of the Wilson Trouble-Shooters Check List and the 40-page bulletin describing the complete Wilson line will be sent on request.

Wilson Tube Cleaners for straight and curved boiler tubes

wilson
PIPE AND TUBE CLEANERS EXCLUSIVELY

THOMAS C. WILSON Inc.
21-11 44th AVENUE, LONG ISLAND CITY 1, NEW YORK

Arabian Refinery Nearing Completion

Arabian American Oil Company's 50,000-barrel refinery at Ras Tanurah on the Persian Gulf north of the Island of Bahrein, is reported nearing completion. Work of enlarging the existing refinery on Bahrein also is well advanced, as is work of laying a pipe line from the mainland to augment the plant's crude-oil supply.

This work is part of the program under which both American and British interests are developing properties in the Middle East. The British are said to be seeking American steel to double capacity of the pipe line from fields in Iraq to the coast, and plans further expansion of refining facilities at Haifa as materials can be made available.

Hugoton Black Plant Objections Overruled

Oklahoma Corporation Commission denied an application for a rehearing of its order of November 24 authorizing Cabot Carbon Company to build and operate a channel-type carbon-black plant near Guymon. The rehearing was asked by operators in the Hugoton gas area.

Protesting that the use of sweet gas from Hugoton was wasteful, opponents of the order claimed that more than 100,000,000 cubic feet of gas are available in other areas.

The commission inserted in the record a letter from WPB stating that there is an immediate need for 380,000,000 cubic feet of gas per day with which to manufacture carbon black, and that it has practically exhausted efforts to find gas from which to produce the required amounts.

Cabot Carbon Company said it had been unable to find gas in sufficient quantities in other areas to meet the requirements of the plant, which will use 30,000,000 cubic feet per day.

Federal Gasoline Revenue Shows Increase Over 1943

Revenue from the federal gasoline tax in 1944 showed an increase of $63,000,000 over 1943, with collections from lubricating oils and pipe-line transportation also showing substantial gains.

Gasoline tax collections for the year aggregated $328,597,398, against $265,303,272 in 1943, while receipts from lubricating oils totaled $56,282,554 against $49,210,861, and pipe-line transportation paid $16,348,217 against $14,264,179.

The year wound up with gasoline tax collections in December at a record high of $39,754,162, an increase of $6,600,000 over the $33,114,838 recorded for November and $15,000,000 above the December, 1943, collections of $24,575,024.

Lubricating-oil-tax receipts also hit a high level at $8,497,386, compared with $6,750,244 in November and $3,697,398 in December, 1943, but returns from the tax on pipe-line transportation were down, $1,473,531 in December against $1,561,819 in the same month.

DSC Juggles Big Funds In Oil Manipulations

Defense Supplies Corporation has authorized total expenditures of $9,550,000,000 it was disclosed January 8 by Jesse H. Jones in a review of activities of Reconstruction Finance Corporation. Dis-

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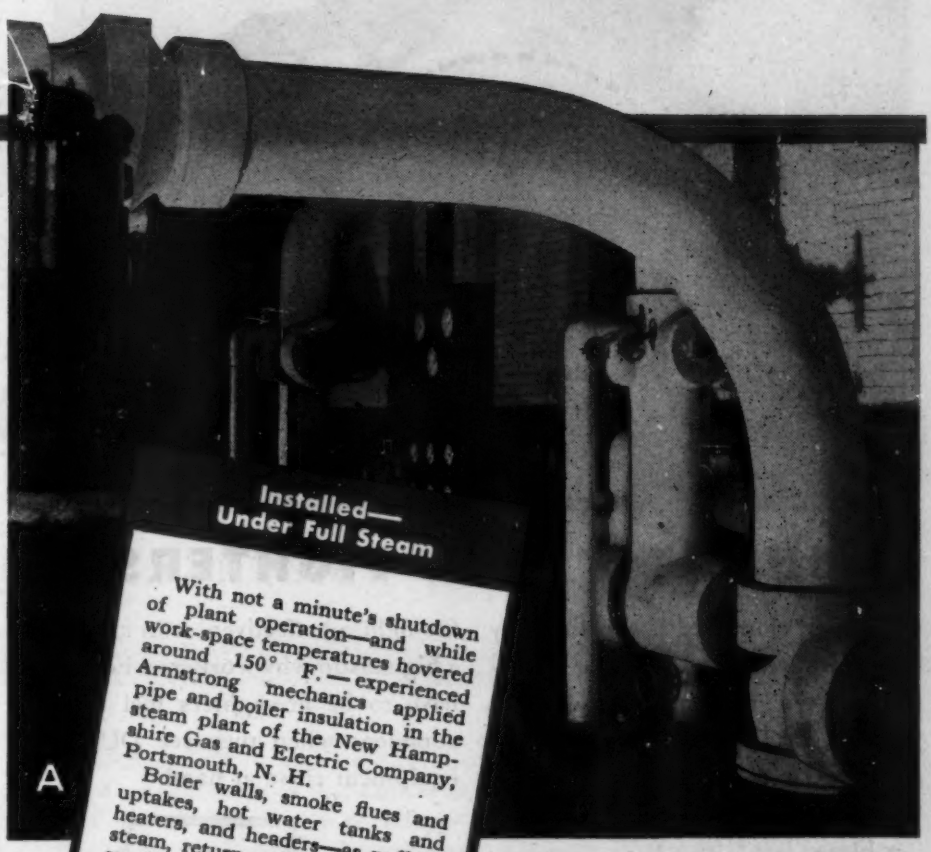

A

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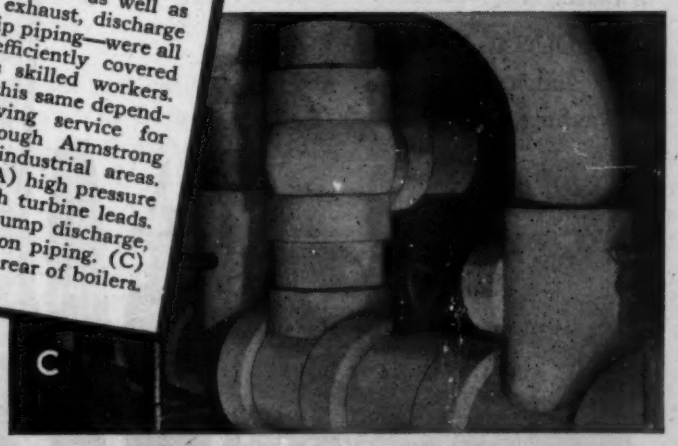
Views show: (A) high pressure steam header with turbine leads. (B) Boiler feed pump discharge, exhaust, and suction piping. (C) Exhaust header at rear of boilers.

B



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bursements for purchase of materials, extraordinary transportation, advances to contractors, and payment of subsidies totaled $5,200,000,000, against which $3,600,000,000 was returned by sale of materials and repayment of advances. Purchases included $2,976,000,000 for aviation gasoline, resold to the armed forces, and $892,400,000 for alcohol for synthetic rubber.

Stripper-well subsidies to December 31 amounted to $11,300,000, with some claims pending, and $297,400,000 was paid for extraordinary transportation of oil to the Eastern Seaboard and $4,000,000 for moving oil to the Middle West, to the end of 1944.

Loans and advances for facilities for aviation gasoline were $190,400,000, of which $84,400,000 has been repaid.

Profit was shown on operation of the emergency pipe lines, with income of $505,700,000, against expenditure of $438,200,000 for purchase of oil and operation of the lines.

AIME Cancels Meeting

American Institute of Mining and Metallurgical Engineers has cancelled its 162nd annual meeting which was scheduled for February 19-22 at New York. Papers scheduled to have been presented will be made available through the institute's publications, it was said.

All American Jet Propulsion

It is the opinion of engineers of Westinghouse Electric and Manufacturing Company that the jet-propulsion engine of American design will "produce more pounds of thrust for a given amount of fuel and pounds of weight than any engine brought from Europe for study." This statement was part of the introduction to a statement that the company is now working on a design, "free of foreign influence" for the Bureau of Aeronautics, Navy Department.

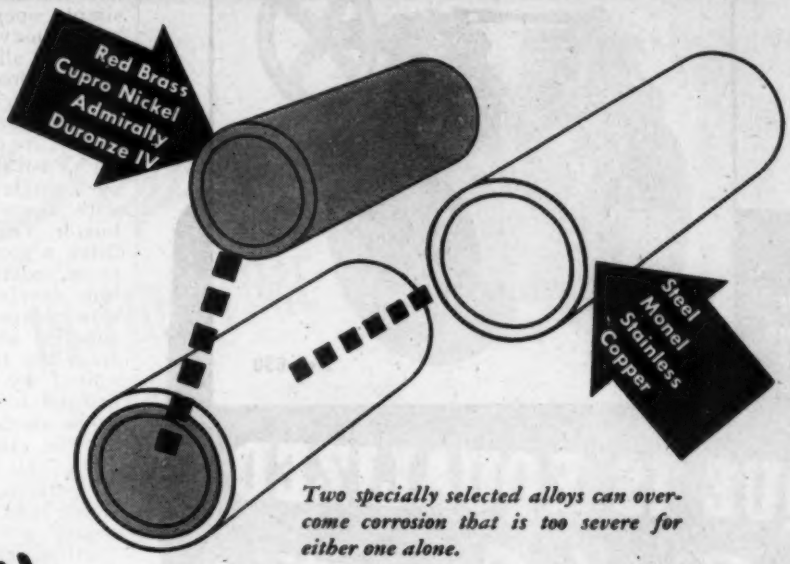
The complete statement gives information on several phases of the gas turbine, as follows:

"Few subjects in recent years have been studied so assiduously, few have commanded so much research work, so much laboratory experimentation, as gas turbines, of which jet-propulsion engines are but one form. Actually an enormous amount of ground has been covered. Probably more has been accomplished in the past two years to make the gas turbine widely practical than in all previous history.

"Essentially, work of three sorts is being done. One is in the field of high-temperature metallurgy, because the success of the combustion-gas-turbine cycle depends on the temperatures in the turbine itself being 1200°F. or more, which is well beyond the highest steam-turbine temperatures. The higher the allowable temperatures the greater the efficiency and the wider the field of usefulness of the gas-turbine cycle as a prime mover.

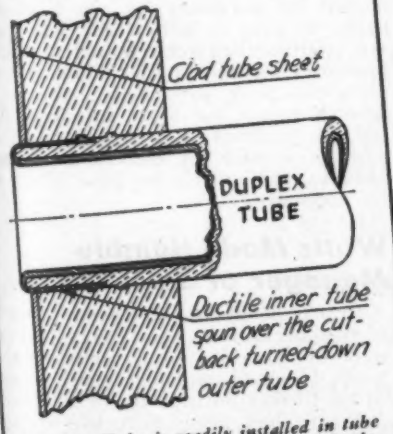
"A second and the most active phase of the activity is the design, building and testing of different units with many variations as to size and arrangements. This includes designs for the three main components of a gas-turbine cycle—axial-flow compressor, combustor, and gas turbine—and the relatively few but important controls and auxiliaries.

"A third activity—sharply limited by more pressing war work—is the investi-



Two specially selected alloys can overcome corrosion that is too severe for either one alone.

How DUPLEX TUBING GIVES A DOUBLE-BARRELED ANSWER TO SEVERE CORROSION PROBLEMS



Duplex Tube is readily installed in tube sheet by any one of several methods, depending on conditions. X-Section shows installation where tube sheet is protected by covering it with same metal as the inside member of Duplex Tubing.

Wherever difficult corrosive conditions are encountered that cannot be met by a single metal or alloy—Bridgeport's Duplex Tubing has been found an effective double-barreled answer!

For in Duplex Tubes two different metals are "drawn" to form a single tube with the inside wall of one material and the outside wall of the other—each selected to withstand the particular corrosive action encountered. Many combinations of metals have been successfully used with excellent results in increasing tube life, and eliminating danger of product contamination.

Combinations of copper and steel are widely used in ammonia refrigeration lines, for example. Others include Admiralty, Cupro Nickel, Duronze IV, Cuzinal and Red Brass combined with low carbon steel, Monel metal, or stainless steel to meet specific conditions.

If you have an unusual or difficult corrosion problem, we will be glad to give you the benefit of our experience. Write us today to our nearest office for The Duplex Technical Bulletin and the Condenser Tube Manual.

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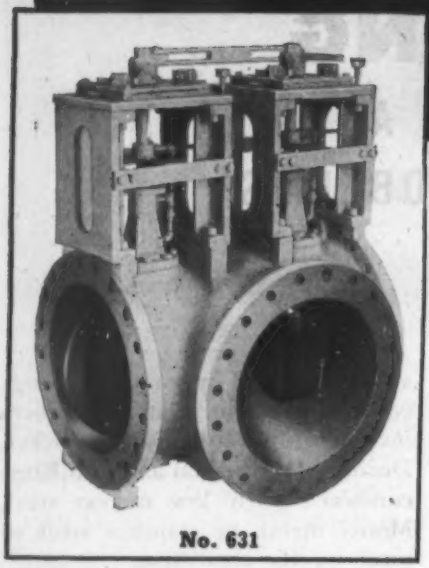

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With a pressure drop across the valve, the vane tends to close itself. The torque on the closed right-hand vane (see illustrations) is opposite to that on the open left-hand vane so that the torque is equalized and no excessive load is placed on the motor in power-operated installations.

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gation of possible uses of the combustion-gas-turbine cycle. This involves extensive thermodynamic and heat-balance calculations for a wide variety of simple open-cycle systems, heat-recovery open-cycle systems, and closed-cycle systems, all predicated on assumed efficiencies, loadings, and costs.

"The great attraction of the combustion-gas-turbine cycle lies in its simplicity, its independence of a water supply. Basically it consists of three units on a single shaft. Liquid fuel is burned with a great excess of air in a combustor. The hot products of combustion drive a gas turbine and, in the simple cycle, exhausts to atmosphere. The turbine develops power to drive an axial-flow compressor on the same shaft that supplied air to the combustor. Power from the turbine in excess of that required by the compressor can be utilized to drive a generator or some other mechanical load.

"The efficiency of a 1200°F. simple open-cycle gas-turbine plant is about 20 percent, which is only about two thirds that of a good steam or gasoline-engine power plant. Also all present combustors and turbines require liquid fuel. The unit, furthermore, is not self-starting. But it is simple in form, is small in weight and bulk, requires no water, and is a rotating device. Efficiency can be increased 10 or 15 percent by adding various heat-recovery devices such as intercoolers for the compressor, regenerators for the combustor, and fuel reheaters. These, on the other hand, add complications and some demand a supply of cooling water.

"It is expected that open-cycle units with approximate maximum ratings of 7500 horse power will be useful as emergency or stand-by generating units on power systems, particularly at the end of long lines or where good or adequate boiler water is lacking. To obtain larger amounts of power for central-station use from units of practical size, it will be necessary to use a closed-cycle system, in which the hot gases are continuously recirculated at higher pressure. Certain special industrial applications look promising, such as to furnish power for blast furnaces. Also the gas turbine is attractive for ship propulsion and for electric-drive locomotives, particularly because of the water economy."

Watts Made Humble Manager of Sales

Frank A. Watts has been promoted from purchasing agent to sales manager of Humble Oil & Refining Company, Houston, and has been succeeded in his former position by F. T. Fendley.

Watts has been with the company since 1919 and has been purchasing agent since 1938 except for 15 months in Washington as director of the materials division of PAW. Fendley has been with the company 25 years, and before joining the purchasing department in 1933 was an engineer in the refining department, first at Baytown and later in the Houston office. He was acting purchasing agent during Watts' leave to the government.

Blazer Bank Director

Paul G. Blazer, chairman of Ashland Oil & Refining Company, Ashland, Kentucky, has been named a director of the Cincinnati branch of the Federal Reserve Bank of Cleveland.

Dependability
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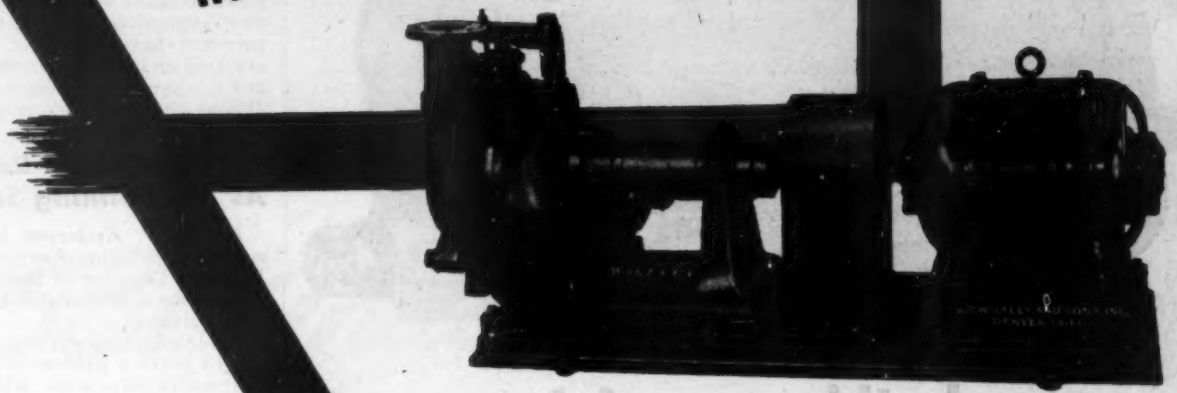

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There are a great many applications for solenoid valves for safety shut-off service and for automatic and remote control. If you are interested in automatic control of the flow of liquids or gases, or of air or hydraulic cylinders, tell us your problem. Write in detail. We shall be glad to make complete recommendations.

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Bergen Superintendent Standard Toledo Plant

W. K. Bergen has been promoted from assistant to superintendent of the Toledo refinery of Standard Oil Company (Ohio), replacing Dr. F. J. Sanders, who has been made superintendent of No. 2 Refinery at Cleveland.

Bergen received a master's degree in chemistry from University of Cincinnati, and joined the company's engineering department at Lima, Ohio, in 1930. Subsequently he was cracking foreman at that plant, went to Latonia, Kentucky, in the same capacity in 1933, and transferred to Toledo in 1940 as assistant superintendent.

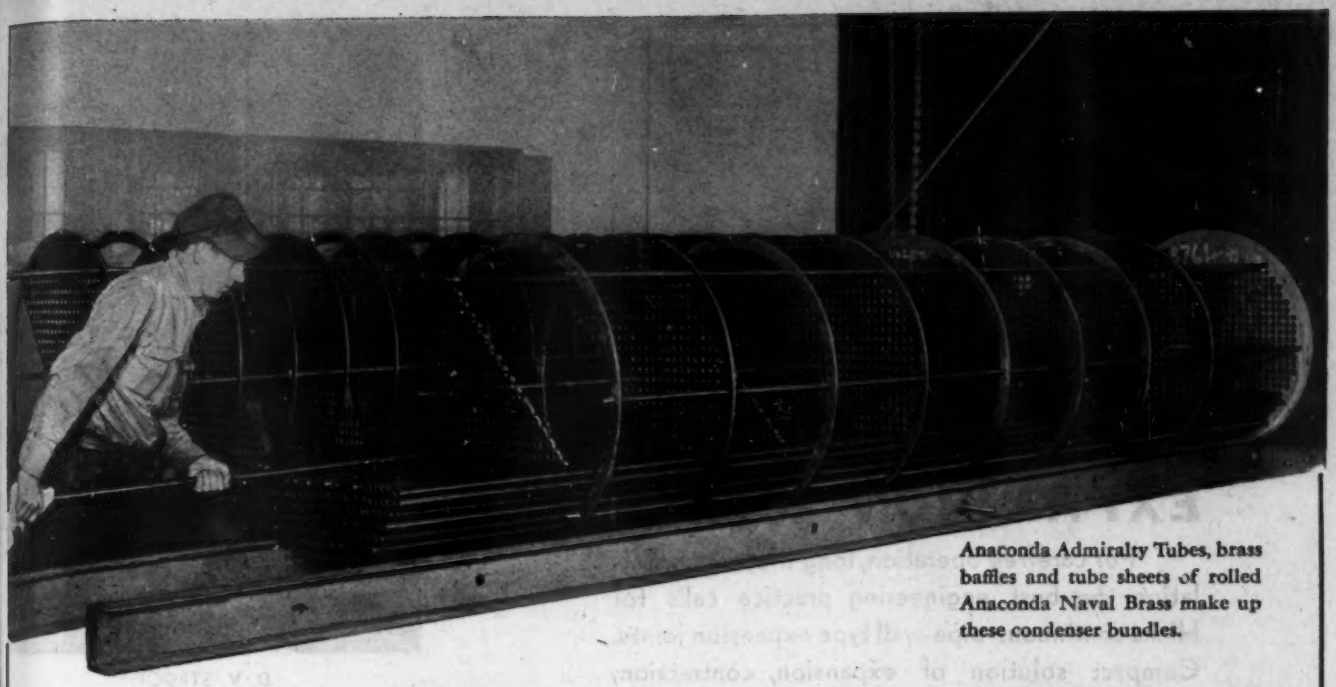
C. O. Rowley, general foreman in the process department, succeeds as assistant superintendent at Toledo, and H. H. Chapman, general foreman in the cracking department, has been placed in charge of all cracking and distillation operations. Rowley and Chapman have been with the company 25 and 29 years, respectively.

R. P. Anderson Resigns As API Refining Secretary

Dr. R. P. Anderson has resigned as secretary of the American Petroleum Institute Division of Refining, and plans to become a resident of Chester County, Pennsylvania.

After graduation from Cornell he was for 13 years a professor of chemistry at that university, after which he was for 7 years chief chemist for United Natural Gas Company at Oil City, Pennsylvania, before joining American Petroleum Institute in 1924. As secretary of the Division of Refining he carried out the recommendations and plans adopted by the general committee of the division, and administered the activities of the numerous divisional committees and subcommittees engaged in automotive research, meeting programs, standardization of equipment, testing methods and specifications, and vocational training. He also was secretary of the advisory committee on fundamental research on the composition and properties of petro-

DR. R. P. ANDERSON



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D. V. STROOP

leum, which sponsors research projects under the institute's program of fundamental research.

In addition to his many duties with the institute, Dr. Anderson particpated in technological activities relating to petroleum in the American Society for Testing Materials, American Standards Association, Coordinating Research Council, International Standards Association, National Fire Protection Association, and other organizations.

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Eikonogen
Cyclopentadecanone
Glyceric aldehyde
Glutaconic acid
Hexamethylene diisocyanate
2-Isopropyl benzoic acid
Ethylene glycol monoallyl ether
2-Methyl-5-isopropyl benzoic acid
3-Methyl-2-ethyl pentane
p-Nitro brombenzene
Pentamethylene chloro or bromohydrin
n-Pentadecanoic acid
1-Phenyl cyclopentan-1-ol
1-Phenyl cyclopentane-1,2-diol
1-Phenyl cyclopentene-1
Succinic dialdehyde
Toluene-3,4-dithiol

CIENCE AND TECHNOLOGY
BSTRACTS

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Traver Road, Ann Arbor, Michigan
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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

iquid Densities of Volatile Hydro-on Mixtures. G. H. HANSON, B. B. ST, AND G. G. BROWN. *Ind. & Eng.* . 36 (1944) pp. 1161-65.

he use of apparent densities for thane and ethane in the liquid phase, gested by Standing and Katz for mating the density of crude oil satu-d with natural gas at high pressures, been extended to liquid solutions of tile hydrocarbons as found in natural oline. The modified expansion factor hod suggested by Gamson and Wat- also appears satisfactory for esti-ing the density of a complex liquid tion such as natural gasoline from composition of the mixture. Several id samples were analyzed by close tionation at low temperature and the sity of the solution determined and pared with the computed densities. results of the work are presented in ular and graphical form. The average or in the use of apparent densities in calculation of the liquid densities of volatile hydrocarbon solutions is 5%, and the average error in the use he modified expansion factor method 2.0%.

hermal Data. XVIII. The Heat Ca-ty, Heat of Fusion, Entropy and e Energy of Ethylbenzene. G. B. HRIE, JR., R. W. SPITZER AND H. M. FMAN. *Jour. Amer. Chem. Soc.* **66** 4) pp. 2120-21.

he heat capacity, heat of fusion and ing point of ethylbenzene were sured in the range 13.34° K. to 41° K. The measurements therefore r the heat capacity of solids and of liquids above the melting point 169° K. Data are presented in tabu-form. The heat of fusion was deter-ed and found to be 2190.3 cal./mole. molal entropy and free energy of ation of liquid ethylbenzene at 16° K. were calculated. The results he calculation are presented.

he Heat Capacity of Gaseous 1,3-adiene from 0 to 100°. D. H. TEMPLE-AND D. D. DAVIES WITH W. A. SING. *Jour. Amer. Chem. Soc.* **66** 4) pp. 2033-35.

onsiderable disagreement has existed ween calculated values of the heat acity of gaseous butadiene and few erimental data has been available. The authors review previous work and describe the apparatus and procedure used in their own determinations. A comparison of the results of the various studies is given in graphical form and a table is included showing the molal heat capacities of 1,3-butadiene at temperatures in the range 5° C. to 105° C. The equation of the straight line representing the data is $C_p^\circ = 3.32 + 0.516T$. As a method of calibration of the apparatus and method the authors determined the capacities of air and n-butane, and from the results of these measurements they concluded that the heat capacities as given are accurate to within 1 part in 100.

Thermodynamic Properties of cis-2-Butene from 15° to 1500° K. R. B. SCOTT, W. J. FERGUSON AND F. G. BRICKWEDDE. *J. Res. Natl. Bur. Standards* **33** (1944) pp. 1-20.

The properties of cis-2-butene, 99.94% pure, were measured. (1) The specific heat of the solid and liquid from 15° to 300° K., (2) the heat of fusion (130.25 international joules per gram), (3) the triple point (134.260° K.), (4) the heat of evaporation at several temperatures between 246° and 293° K. and (5) the vapor pressure from 200° to 296° K., were determined. The normal boiling point (3.718°), the volume of the saturated vapor, the enthalpy and entropy of the solid and liquid from 0° to 300° K., the enthalpy, entropy and specific heat of the vapor in the ideal gas state from 245° to 300° K. were calculated. Spectrographic data were used in calculating the thermodynamic functions from 300° to 1500° K. At the lower temperatures good agreement is obtained when it is assumed that a barrier of 700 calories per mole restricts the internal rotation of the methyl groups. The equilibrium constant and the equilibrium proportions in the ideal gas state of the cis-trans isomerization of 2-butene were calculated from 300° to 1500° K.

Vapor-Liquid Equilibrium Constants for Benzene, Toluene, and Methyl-Cyclohexane. H. G. DRICKAMER AND J. G. BRADFORD. *Ind. & Eng. Chem.* **36** (1944) pp. 1144-5.

Vapor-liquid equilibrium constants for benzene, toluene, and methyl cyclohexane are presented in graphical form. The equilibrium constant $K = y/x$ is plotted against the pressure in pounds per square inch absolute. The pressure range is from 0 to 600 pounds absolute. Data for methylcyclohexane were obtained from unpublished sources. Although the charts are rigorously applicable only to solutions of an ideal nature, it is believed that they may frequently be helpful in calculations involving solutions that vary somewhat from the ideal.

Critical Solution Temperatures with Cyclic Hydrocarbons. A. W. FRANCIS. *Ind. & Eng. Chem.* **36** (1944) pp. 1096-1104.

Critical solution temperatures are reported for sixty organic solvents, each with one or several of thirty-five aromatic hydrocarbons and three naphthenes. For each solvent the points agree approximately with a smooth function of the total number of paraffinic carbon atoms in the side chains of the hydrocarbons. In alkylbenzene the temperatures are nearly parallel to the boiling points of the hydrocarbons. Moreover, for most aliphatic solvents the critical solution temperatures are nearly the same for corresponding derivatives of benzene and naphthalene, so that they can be used to estimate the paraffinicity of an aromatic mixture. The effects of substituent groups in the solvents upon miscibility are estimated. The hydroxyl, amino, and carboxyl radicals raise the temperatures roughly 200° C. or more, and the nitro group about 150° C. Other radicals have much less effect. Selectivities of solvents for aromatic hydrocarbons with respect to paraffins are about six times as great as those for naphthenes. A composite arrangement of solvents and hydrocarbons is devised showing qualitatively the mutual solubility of any pair of included substances as liquids; by use of the relations of this and other papers, almost any liquefiable organic compound can be included. The data are presented in tabular form in considerable detail.

The Measurement of Boundary Tension by the Pendant-Drop Method. II. Hydrocarbons. G. W. SMITH. *J. Phys. Chem.* **48** (1944) pp. 168-72.

The author describes an improved technique for the precise measurement of surface tension by the pendant-drop method. The following data were obtained at 20° C.: Octane, 21.7; 2-methylheptane, 20.7; 3-methylheptane, 21.2; 4-methylheptane, 21.2; 2,5-dimethylheptane, 19.8; 2,2,4-trimethylpentane, 18.9; o-xylene, 30.1; p-xylene, 28.5; ethylcyclohexane, 25.8; heptane, 19.7; cyclohexane, 25.2; cyclohexene, 26.6; benzene, 29.2;

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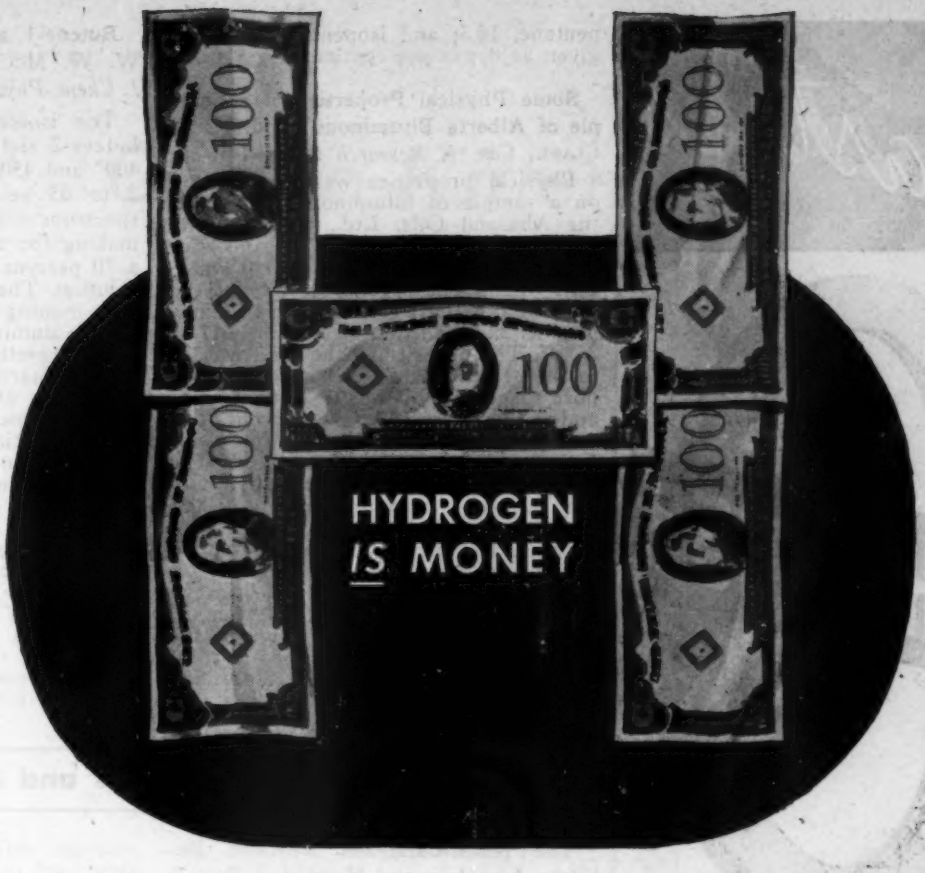

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pentane, 16.3; and isopentane, 15.8, all given as dynes per centimeter.

Some Physical Properties of a Sample of Alberta Bituminous Sand. K. A. CLARK. *Can. J. Research* **22** (1944).

Physical properties were determined on a sample of bituminous sand from the Abasand Oils, Ltd., quarry in its natural state of packing. The sand contained 17 percent bitumen and 0.9 percent water. The specific gravity of the mineral aggregate contained in the sample was 2.65, and that of the oil, 1.017 at 25° C. The porosity of the sand was 39 to 40 percent, while saturation of the pore space with oil was 80 to 85 percent and with water, 3.4 to 4.5 percent. The total saturation with oil and water was believed to be almost complete. The coefficient of thermal conductivity of the sample was approximately 0.0035 c.g.s. at 45° C. in its natural state of packing. The specific heat of the mineral content of the sample was 0.18 cal./g/° C. and that of the oil content, 0.35 cal. for the temperature range between 0° and 100° C. The calorific value of the bituminous sand containing 83 percent carbon, 10.22 hydrogen, 3.78 sulfur and 0.46 nitrogen, was 17.860 Btu/lb.

Butene-1 and Butene-2 Equilibrium. W. W. MCCARTHY AND J. TURKEVICH. *J. Chem. Phys.* **12** (1944) pp. 405-8.

The isomerization of butene-1 to butene-2 and vice versa was studied at 400° and 450° C. at contact times from 2 to 65 seconds. Infrared absorption spectrum measurements were used in making the analyses. The butene-2 was a 70 percent cis- and 30 percent trans-solution. The gases were preheated before coming in contact with the activated alumina. The amount of each isomer resulting in given contact time is shown starting with either material. When the contact time was long there was polymerization to a low-boiling liquid especially when feeding butene-1. Using butene-2 and a temperature of 450° C. equilibrium was reached in a few seconds but took a longer time with butene-1. At 400° butene-2 came to equilibrium more slowly and butene-1 failed to reach equilibrium. The free energies of the three butenes were calculated at the working temperatures and the mole percentages of the butenes at equilibrium were determined. These were in good agreement with the values found experimentally.

Chemical Compositions and Reactions

The Metal-Catalyzed Reaction Between Acetylene and Hydrogen. Part I. Nickel Catalysts. J. SHERIDAN. *J. Chem. Soc.* (1944) p. 373.

In the hydrogenation of acetylene ethylene is produced five times as rapidly as ethane until most of the acetylene is hydrogenated. The reaction products other than C_2 hydrocarbons have an empirical composition of approximately C_4H_7. They are formed in yields of 55-60 percent of the acetylene not recovered. The initial reaction when using catalysts of constant activity is of first order with respect to hydrogen and of approximately zero order with respect to acetylene. An increase from 1:8 to 8:1 in initial hydrogen: acetylene ratio brings about an increase of 40 to 68 percent in the yield of C_2 hydrocarbons expressed in terms of acetylene not recovered. Ethylene, when added to the system, acts primarily as an inert diluent. It is less strongly adsorbed than acetylene on nickel. The catalysts used have negligible action on acetylene alone.

Effects of Temperature, Contact Time, and Water Vapor on the Olefin-Aromatic Ratio in the Dehydrogenation of n-Heptane with Chromia-Alumina. W. J. MATTOX. *Jour. Amer. Chem. Soc.* 66 (1944) pp. 2059-63.

Variations in the ratio of olefins to aromatics produced during the dehydrogenation of n-heptane with chromia-alumina as influenced by temperature, contact time or space velocity, and water vapor were studied. At contact times below 1.5 seconds at 500° C., 0.5 second at 550° C. and 0.15 second at 600° C. the dehydrogenation products contained a larger proportion of heptene than of toluene. At longer contact times, and at the corresponding temperatures, the aromatic predominated. The effect of temperature was found to be as pronounced as that of contact time on the olefin-aromatic ration. For any given contact time, an increase in temperature resulted in a decrease in ratio. Addition of water vapor in the ratio of 0-1 mole per mole of heptane preferentially retarded the formation of aromatics so that with 0.5 mole or more of water per mole of heptane the olefin-aromatic ratio was greater than 1. With the direct addition of water, a ratio of 4.8 was obtained with a total olefin-aromatic conversion of 16.4 weight percent of the charge per pass; the toluene-heptene yield amounted to 82% of the heptane decomposed.

Nitration of 2,3-Dimethylbutane. M. H. DANZIG AND H. B. HASS. *Jour. Amer. Chem. Soc.* 66 (1944) pp. 2017-19.

The authors report on an extension of the study of vapor phase nitration of the paraffins to the nitration of the hexanes. The paper deals specifically with the nitration of 2,3-dimethylbutane. This hydrocarbon is of interest because it possesses two tertiary hydrogen atoms and it is important to know whether these tertiary hydrogen atoms are replaced in the nitration process to form the corresponding dinitroparaffin. The nitroparaffins obtained were identified as nitromethane, 2-nitropropane, 3-methyl-2-nitrobutane, 2,3-dimethyl-2-nitrobutane and 2,3-dimethyl-1-nitrobutane. The isolation of these five products and the absence of a dinitroparaffin serve as additional confirmation of the generalizations concerning the vapor-phase nitration of the aliphatic hydrocarbons.

Vapor Phase Hydrogenation of Naphthalene and Tetralin Over Nickel Catalyst. W. J. CERVENY AND B. B. CORSON. *Jour. Amer. Chem. Soc.* 66 (1944) pp. 2123-24.

The literature bearing on the vapor phase hydrogenation of naphthalene is briefly reviewed. On account of the conflicting results as reported by several

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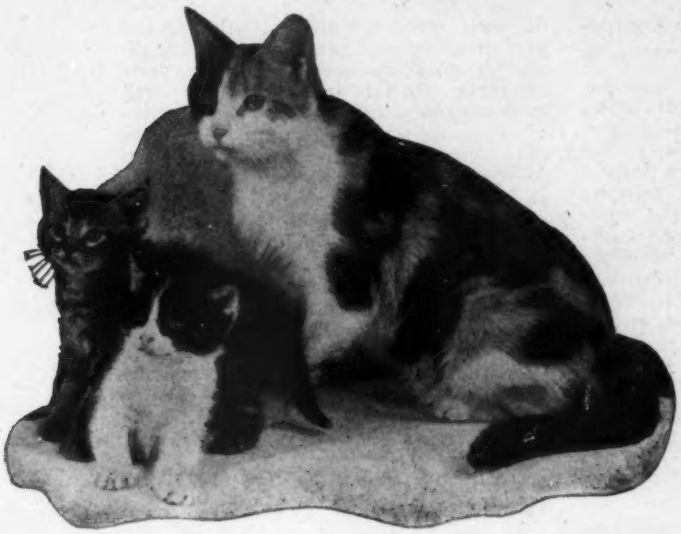

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investigators the authors studied the vapor phase hydrogenation of naphthalene over nickel and found that decalin was readily obtained. The apparatus used in the work is described and shown diagrammatically. The results obtained at several temperatures in hydrogenating naphthalene and tetralin in the vapor phase over nickel catalyst are reported in tabular form.

Manufacture: Processes and Plant

Blending Aviation Gasoline Components. S. S. LUKOFSKY. *Ind. & Eng. Chem.* **36** (1944) pp. 1085-87.

Mathematical principles are discussed that underlie the blending of liquid components to meet simultaneously the specifications for three extensive properties of the aviation gasoline solution when the volume of one of the components is known to be limiting. Reference is made particularly to blending aviation gasoline although the treatment is entirely general. The physical properties in question are assumed to be linearly dependent either upon the volumetric or molar proportion of the components in the solution.

Determining Needed Relieving Capacity for Rupture Diaphragms. T. S. MURPHY, JR. *Chem. & Met. Engr.* **51** No. 12 (1944) pp. 99-103.

The question of the required relieving capacity for various types of systems that can be subjected to destructive overpressures must necessarily be solved in the application of rupture diaphragms. Some problems are readily solved, but others are extremely difficult, or may defy exact solution. The source or sources of the overpressure must be determined. What rate of pressure increase may occur, or to what maximum pressure will the system be raised if the pressure is unrelieved? The author discusses several typical problems and outlines solutions of them.

Pure Hydrocarbons from Petroleum. J. GRISWOLD, J. W. MORRIS, AND C. F. VAN BERG. *Ind. & Eng. Chem.* **36** (1944) pp. 1119-23.

The authors describe the development and performance of screen-plate columns that have been used for general-purpose hydrocarbon fractionations and in pilot-plant processes for separating pure hydrocarbons from petroleum in the University of Texas laboratories over the past several years. The development and performance of three designs of all-metal screen-plate fractionating columns are reported. The characteristics of six different screens were determined, and performance of 1.5-inch and 2-inch diameter columns are given with plate efficiency-rate data on n-heptane-methylcyclohexane at total reflux. The features of these columns are ruggedness, ease of construction, and relatively high capacities, with maintenance of efficiency at high rates characteristic of plate-type columns. Maximum boil-up rates are 73 ml. per minute (1.2 gallons per hour) for a 1.5-inch column and 4 gallons per hour for a 2-inch column. Maximum HETP occurs at maximum boil-up, and the corresponding values are 1.8 and 3.2 inches, respectively. The article is well illustrated with diagrams showing details of construction. Data are presented in tabular and graphical form.

Distribution Equation. J. A. CAMPBELL. *Ind. & Eng. Chem.* **36** (1944) pp. 1158-61.

In many industrial processes the distribution of a substance between two phases is important in design and operation. Several relationships are available for the calculation of such heterogeneous distributions, as, for example, Henry's law, Raoult's law, distribution law, and Freundlich equation. It is possible to obtain a simple equation that coordinates the data for the great majority of distribution equilibria if the physical significance of the terms involved is neglected. When the logarithm of the concentration in one phase is plotted against the logarithm of the concentration in the other phase, straight lines are obtained in many instances and the deviations in the majority of cases are slight. The equation is identical in form with the Freundlich equation for adsorption isotherms but the application to the solubility of gases and the distribution of the solutes between two liquid phases or between solid and liquid phases considerably widens in scope. The equation is readily adaptable to the usual methods of calculation involved in absorption and extraction. Typical data are presented in tabular and graphical form and illustrative calculations are given.

Products: Properties and Utilization

Oil-Paper Dielectrics. J. D. PIPER AND N. A. KERSTEIN. *Ind. & Eng. Chem.* **36** (1944) pp. 1104-10.

For several years the authors and their colleagues have been endeavoring to obtain fundamental data concerning the physiochemical nature of substances that can cause significant increases in the power factors and conductivities of insulating oils and impregnated papers. The method used consists simply of adding to an oil with a very low conductivity, various concentrations of highly purified materials of the types selected to represent constituents or deterioration products of commercial insulating oils, and of determining the resulting changes in dielectric properties. When insulating paper is involved, the oil and the mixtures derived from it are used to impregnate the paper. Cable and filter papers, impregnated with liquid paraffin solutions containing a few thousandths millimole of lauryl sulfonic acid per gram of oil, have alternating current conductivities that are many times greater than the conductivities of the solutions. The acid is strongly sorbed by the paper. If a small fraction of the total sulfur compounds in most commercial impregnating oils should become oxidized in service to sulfonic acids, some of the high power factors that im-

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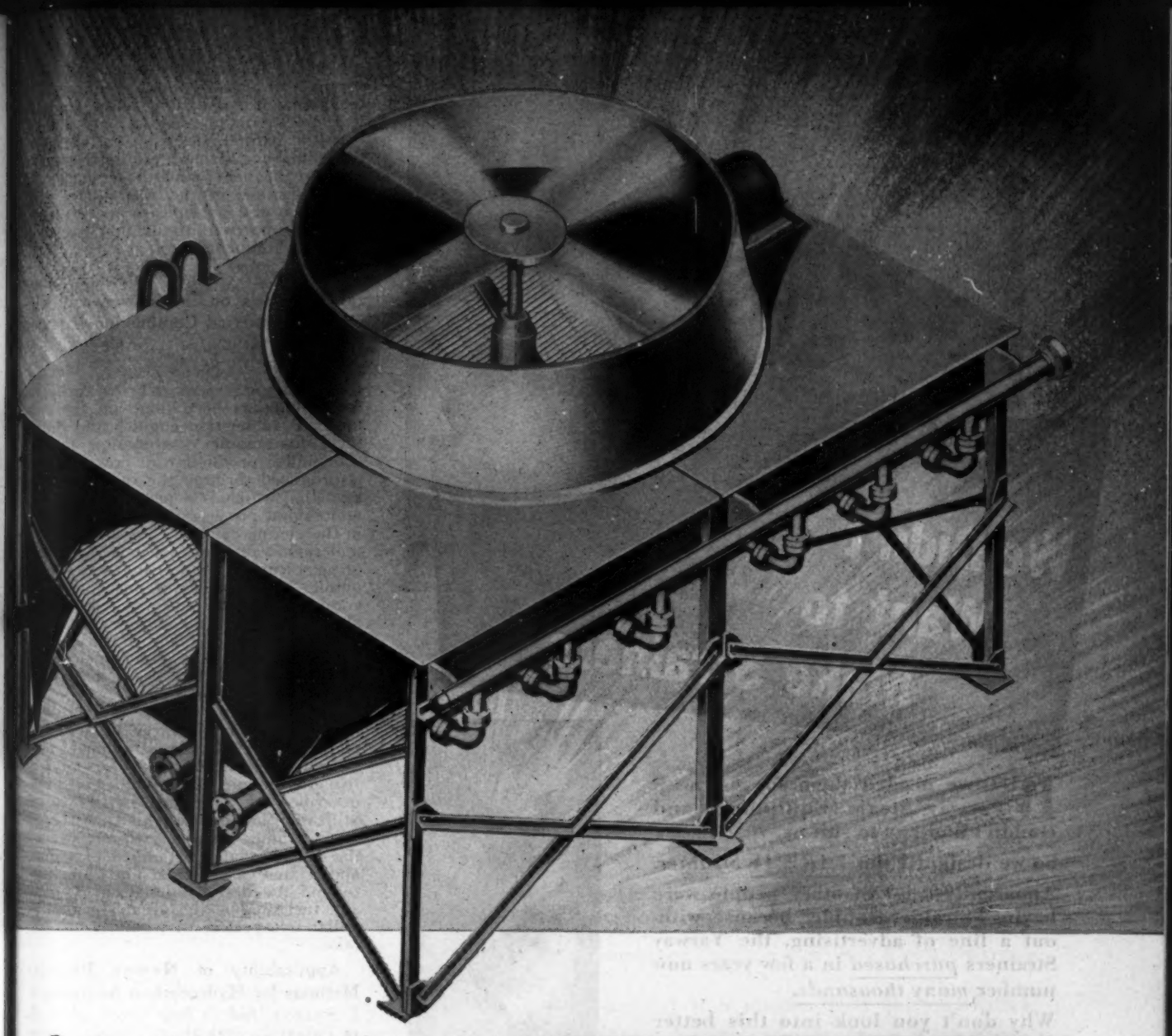

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pregnated insulations often acquire in service can readily be explained. The technique of Balsbaugh, Assaf, and coworkers for distinguishing between the types of degradation products that exert their influence through preferential sorption by the paper and those that exert their influence in the impregnant may become useful analytically if the technique is improved to include values at very low frequencies.

The Effect of the Molecular Structure of Fuels on the Power and Efficiency of Internal Combustion Engines. C. F. KETTERING. *Ind. & Eng. Chem.* **36** (1944) pp. 1079-85.

The author reviews in broad terms the work that has been done on fuels for internal combustion engines and on the fuel plus engine combination for the economical production of power. Power is produced through the reaction "combustion," which is a name for the little understood process of what takes place in the engine cylinder. Upon this poorly understood reaction depends the service of petroleum and motor industries to the public. People became conscious of the combustion disturbance called "knock" about 1912, and the author briefly reviews the studies made of this subject since that time. The importance of molecular structure has been increasingly recognized. As a matter of historical interest the author reviews the results of investigations made in the 1920s and depicts the results in graphical form. Recent work in the production of 2,2,3-trimethylbutane or triptane is briefly described and the possibilities of the utilization of a fuel of this type are outlined. Studies are under way to evaluate the commercial possibilities of triptane and related compounds. The objective is to find the best combination of engine and fuel to give the greatest value per dollar irrespective of what form it may take.

Applicability of Newer Physical Methods for Hydrocarbon Analyses. W. J. SWEENY. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 723-27.

Much progress has been made in applying the newer techniques of physics to hydrocarbon analysis, and greater advances are to be expected. No one method is self-sufficient, and its usefulness is dependent largely on judicious combination with other methods. The equipment available at the Esso Laboratories-Research Division is listed, and includes such instruments as infrared spectrograph, an infrared spectrophotometer, ultraviolet spectrophotometers, an emission spectrograph, a mass spectrograph, and a Raman spectrograph. Great progress has been made in applying the principles of physics to the analysis of hydrocarbons, but for security reasons little of this work has been published. Many highly complex problems are greatly simplified by a judicious use of the newer method. The author summarizes the advantages resulting therefrom in the analyses of various typical petroleum products.

Petroleum Coke. Formation and Properties. A. G. V. BERRY AND R. EDGEWORTH-JOHNSTONE. *Ind. & Eng. Chem.* **36** (1944) pp. 1140-44.

The trend of modern cracking processes is toward the use of distillate charging stocks rather than residues,

and this raises the problem of disposing of heavy residues, both straight-run and cracked. Such residues can be hydrogenated or coked. The former is a costly process that has not earned profits under peacetime conditions. Coking is, however, a well-established refinery procedure. However, petroleum coke has received relatively little study. Petroleum coke is essentially a disperse system composed of graphite-like crystallites embedded in an organic matrix. Experiments on the coking of a cracked asphalt under different time-temperature conditions show that the coking process can conveniently be regarded as taking place in four stages, corresponding to the production of pitch, semi-pitch, asphaltic coke, and carboid coke. The properties of these substances are described, and their bearing on the quality and commercial value of petroleum coke is indicated. The results of the experimental work are presented in some detail in tabular and graphical form.

Determination of o-Xylene in Recycle Styrene. R. P. MARQUARDT AND E. N. LUCE. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 751-3.

The recovery of unpolymerized styrene is an important factor in the production of Buna S rubber. Impurities such as 1,4-vinylcyclohexene, ethylbenzene, isopropylbenzene, n-propylbenzene, and o-xylene accumulate in varying amounts, thus requiring purification to make utilization of the unpolymerized styrene possible. All of these impurities except o-xylene, which boils at 144° C. (styrene boils at 145-146° C.) are easily removed by distillation. Since o-xylene remains with the styrene it is important to be able to analyze mixtures of these substances. A procedure for determining o-xylene in the presence of alkylbenzenes and olefinic compounds comprises removing the unsaturates with mercuric acetate, nitrating the o-xylene and other alkylbenzenes, and, using a modified Bost-Nicholson reaction, measuring the color produced by dinotri-o-xylene in a suitable photoelectric colorimeter. It is possible to detect less than 0.01% of o-xylene in samples largely composed of unsaturated hydrocarbons.

Spectrophotometric Study of the Oxidation of Quenching Oils. G. L. CLARK AND W. I. KAYE. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 740-45.

Little information has been available on the choice and performance of quenching oils for use in the large-scale production of aluminum alloy castings, especially for airplane motors. In one large foundry it was found that the strain residual in quenched castings increased markedly with continued use or aging of a well-known quenching oil. The quenching operation involves rapid cooling from a temperature of 480° C. to approximately 45° C. The hot quenching evidently resulted in oxidation of the oil and production of a by-product which in some manner impaired the heat-conduction properties of the oil. A spectrophotometric study was undertaken to evaluate the changes occurring in the oil, and was extended to a study of the rate of oxidation of several other commercial oils recommended for quenching. Studies were made with and without addition agents and in the presence and absence of the aluminum alloy as catalyst. Spectrophotometric data are

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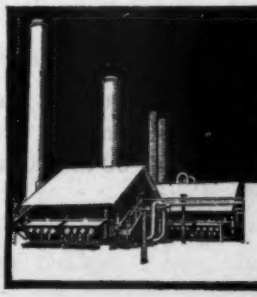

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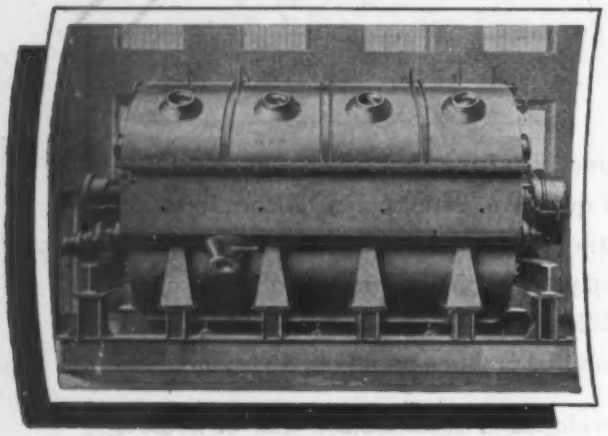

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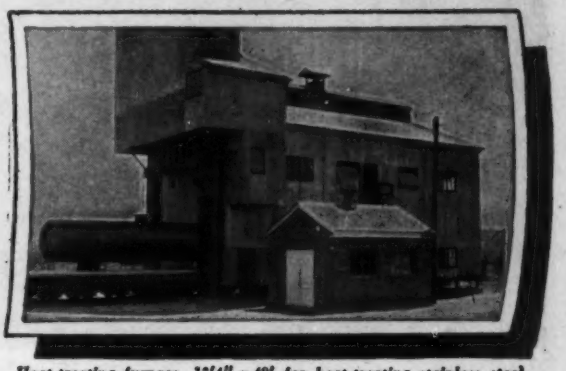

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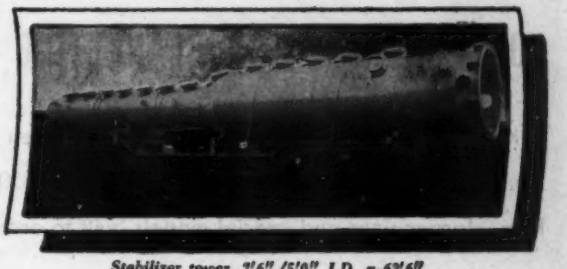

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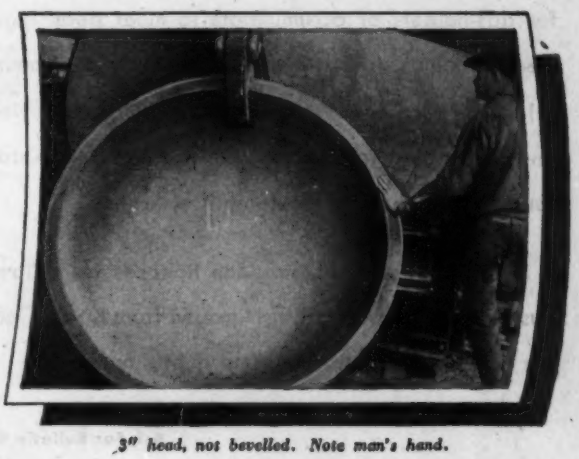

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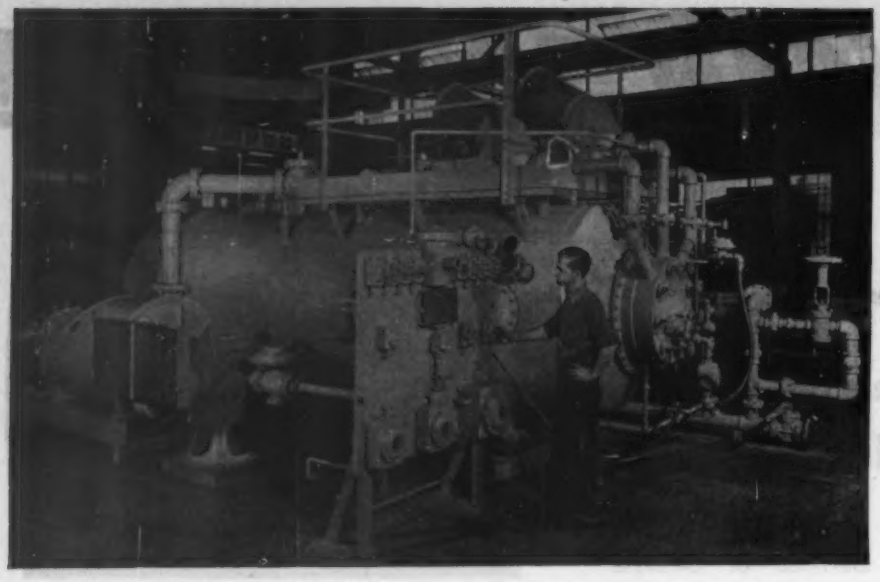

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believed related to the light scattered by colloidal particles or precipitable substances as indicated by absorption curves and electron micrographs. Oxidation stability and absence of precipitable polymer particles are correlated with the quality of quenched castings as measured in terms of residual strain.

Book Reviews

Commercial Waxes, Natural and Synthetic

Edited by *H. Bennett.* 583 pages. Chemical Publishing Company, 26 Court Street, Brooklyn 2, New York. Price, $11.00.

This book discusses in detail all classes of waxes—mineral, vegetable, animal, insect, synthetic and compounded. Data such as melting point, form and fracture, purity, hardness, flexibility, moldability, adhesiveness, solubility and many other properties, including sources and uses, are all listed in this comprehensive study. Of particular value is the section on handling and compounding waxes; tables show compatabilities of waxes with each other, as well as resins, plastics and other materials.

Included is a glossary of terms and wax formulary giving the most useful formulae of commercial materials containing waxes, such as adhesives, agricultural specialties, materials of construction, protective and decorative coatings, soaps, cleaners, etc.

Paraffin wax, the author points out, is the most commonly used commercial wax. Essentially a by-product (often considered a nuisance) of the oil industry, annual production and use in the United States is in excess of 500,000,000 pounds. Considering its importance, little is found in the literature concerning its composition, manufacture or use. Being a variable mixture of organic compounds, it has not appealed to pure science as worthy of thorough investigation. Practical investigation has been in laboratories of either suppliers or consumers who have regarded the fruits of their studies as trade secrets. All available of such data is reviewed in the book.

Prevention of Benzene-Air Explosions by Addition of Nitrogen and Carbon Dioxide

Report of Investigations 3787, by *G. W. Jones.* Bureau of Mines, Department of the Interior, Washington 25, D. C. Free.

Benzene vapor can be handled safely in industrial plants by adding correct amounts of inert gases to the benzene. Graphs and tables are provided for determining inflammability limits, and the laboratory also can figure the percentage of oxygen in the mixtures that must not be exceeded if the mixtures are to be kept non-inflammable. By application of this information, combustible mixtures containing benzene can be removed safely from containers or equipment, or the mixtures may be introduced into such equipment originally containing air, without creating inflammable atmospheres. This is possible if the proper volumes of inert gases—nitrogen or carbon dioxide, or mixtures of the two, are present in the proper concentrations when the benzene is introduced.

Included in the report are tables showing inflammability limits of other industrial gases: coke-oven gas, hydrogen-nitrogen and hydrogen-carbon dioxide mixtures, carbon monoxide-nitrogen

NOW YOU CAN MAKE BETTER-THAN-VEGETABLE WAXES FROM INEXPENSIVE PARAFFINS

BETTER-THAN-VEGETABLE waxes are now being produced by the addition of Litholite A (Foote Lithium Stearate) to paraffins.

LITHOLITE A OVERCOMES OBJECTIONS

The disadvantages of the paraffins, low melting point or tackiness at room temperatures, are substantially offset by the addition of Litholite A. Lithium Stearate inhibits crystalline growth in macro-crystalline paraffin forming a micro-crystalline structure; thus from a cheap macro-crystalline paraffin wax, expensive micro-crystalline wax can be produced at low cost. Litholite A changes macro-crystalline paraffins from a very soft, greasy mass to a tough, rubbery material which is resilient, unlikely to break or chip, with about 3 times the tensile strength of ordinary paraffin, and a melting point 50% above even the vegetable waxes!

PRODUCES A "DRY WAX"

Most low melting waxes with macro- and micro-crystalline paraffin are greasy and tacky to feel. Lithium Stearate overcomes this and produces a so-called dry wax.

MANY POSSIBLE USES

The possibilities for lithiated paraffins include substitution for carnauba in liquid and wax cake polishes, a low cost, high melting point wax for electrical equipment, and numerous specialties such as in cosmetics. For further information on present and post war uses, please write us.

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In a glass bomb such as this, Foote produces pure Ductile Zirconium by deposition. Ductile Zirconium is rapidly increasing in use, becoming the seed of many new and interesting developments. The deposition process, improved and perfected by Foote engineers, is only one example of Foote's forward march in ores, minerals, alloys and chemicals.

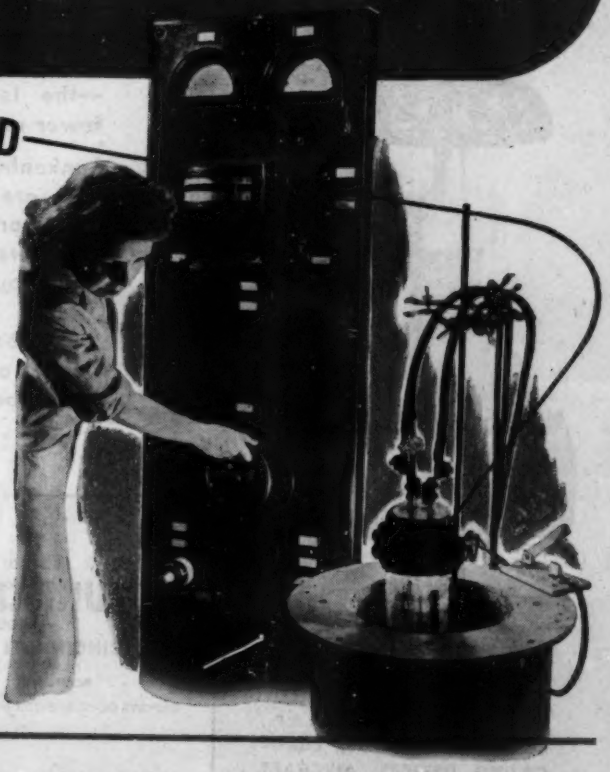

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Fig. 2125
125 lb. S. P. Bronze Gate
Double Disc, Rising Stem

Fig. 123
"N-M-D" Globe
(Non-Metallic Disc)

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and carbon monoxide-carbon dioxide mixtures, methane-nitrogen and methane-carbon dioxide mixtures, ethylene-nitrogen and ethylene-carbon dioxide mixtures, ethane-carbon dioxide mixtures. Also listed are the composition and limits of inflammability of such air-free gases as coke-oven gas, coal gas, carbureted water gas, mixed natural and water gas, oil gas, water gas, producer gas, and blast-furnace gas.

Bureau of Mines Reports Gas-Condensate Research

Supplying additional technical information on the gaseous and liquid components of hydrocarbons obtained from gas-condensate type reservoirs in Arkansas, Louisiana, and Texas, the Bureau of Mines has published a report on the thermal expansion of pressure samples from this type of well, Dr. R. R. Sayers, Bureau Director, announced today.

Because of the importance of the condensate in the manufacture of aviation gasoline and other petroleum products, efforts have been intensified to establish the true characteristics and behavior of the gaseous and liquid components of the reservoirs, Dr. Sayers said. As a result of bureau research much technical information hitherto unavailable has been furnished for the guidance of operators in fields of that type.

The production of condensate involves handling large volumes of well fluids in both the gas and liquid phases and at various temperatures and pressures. Although the relationships between the pressure, volume, and temperature of these well fluids in the gas phase are well known, similar information on these fluids in the liquid phase is meager, the bureau's publication states.

Issued in cooperation with the American Gas Association, the bureau's recent report marks another contribution in its long-range program of applied research on this subject. In introducing the report, the authors, R. Vincent Smith, associate chemist, M. A. Schellhardt, natural-gas engineer, and E. J. Dewees, associate petroleum engineer, all of the Bureau of Mines Petroleum Experiment Station at Bartlesville, describe the apparatus used and the laboratory procedure followed and discuss data obtained from a study of the pressure, volume, temperature relationships of three liquid samples taken under separator pressure in the field. Ten other liquid samples used in the experimentation were formed by progressive reductions of the saturation pressures of the initial separator-liquid samples by differential liberations of part of the dissolved gases.

A copy of the publication, Report of Investigations 3772, "Thermal Expansion of Pressure Samples of Hydrocarbon Liquids from Gas-Condensate Wells," may be obtained free by writing the Bureau of Mines, Department of the Interior, Washington 25, D. C.

West Texas Black Plant To Burn Residue Gas

Construction is under way on a carbon-black plant to be operated by United Carbon Company for Defense Plant Corporation near Odessa, in West Texas. The plant will take 60,000,000 feet daily of residue gas from Cities Service Oil Company's gasoline plant at North Cowden, and from three Phillips Petroleum Company plants, at Goldsmith, Pennwell and McElroy.

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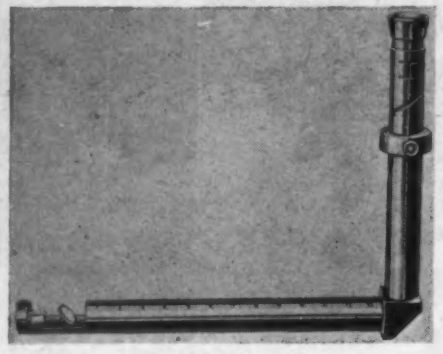
Inspection Tool

POLAN INDUSTRIES

Polan Industries, Huntington, West Virginia, has announced the Polan Borescope available for private industry. The instruments originally were designed for the internal surface inspection of gun bores.



Polan Borescope

The instrument, made in several models for different uses, consists of a combination of lenses and lighting arrangements by which it is possible to visually inspect the interior of tubular bodies from 13/16 to 9 inches in diameter and in lengths up to 30 feet. Design is rugged for every-day use.

Alkali- and Acid-Resistant Cement

THE U. S. STONEWARE COMPANY

The U. S. Stoneware Company, Akron, Ohio, has announced "Duracite," a furane-base resin cement described as resistant to most inorganic acids, organic acids, alkalies of any degree of concentration, oils, and solvent; has high compressive and tensile strength, and temperature range to 350 or 375°F. It can be used as a mortar for acid-proof masonry in tank linings, floors, sewers, towers, and for other installations handling alternately acids and alkalies.

"Duracite" comes in the form of a liquid and powder, and can be stored indefinitely.

Hole-Cutting Tool

BRUNO TOOLS

Bruno Tools, Beverly Hills, California, has perfected a new, all-purpose hole cutting tool, for cutting holes in wood, steel, brass, hard rubber, aluminum, fibre, plastics and problem materials which might necessitate the use of a torch. Two sizes are available: One model cuts holes to any diameter from ⅝-inch to 1¼-inch through ⅛-inch thickness. The other model covers all expansions from 1 to 2½ inches through thicknesses up to ⅜-inch. The tools are designed to operate in light drill presses, portable drills, or breast drills and are also available with square shanks for use in hand braces.

The cutter consists of a drill which starts the hole and also serves as a pilot for the tool, a hardened body with a milled slot into which is set a specially-ground high-speed steel tool bit, and a hardened and ground shank. Adjustment is obtained by loosening the hexagon bolt which holds a firm locking clip, and sliding the blade to the correct distance from the pilot.

Paint-Spray Pump

ALEMITE DIVISION, STEWART-WARNER CORPORATION

Alemite Division of Stewart-Warner Corporation, 1826 Diversey Parkway, Chicago, has announced availability of "Versatal" material pump, developed for the Navy to apply protective coatings to ship bottoms. These pumps are designed to dispense and apply a wide variety of materials, including all types of paints, insulating materials, fibre and cement coatings, etc. It operates on air power and one to six operators may work at once with as many spray heads, through extended lengths of hose.

The material is delivered from the pump at pressures 4½ to 5½ times air pressure introduced to the pump. It is available in several types and sizes.

Oil Packaging Machine

PACKAGE MACHINERY COMPANY

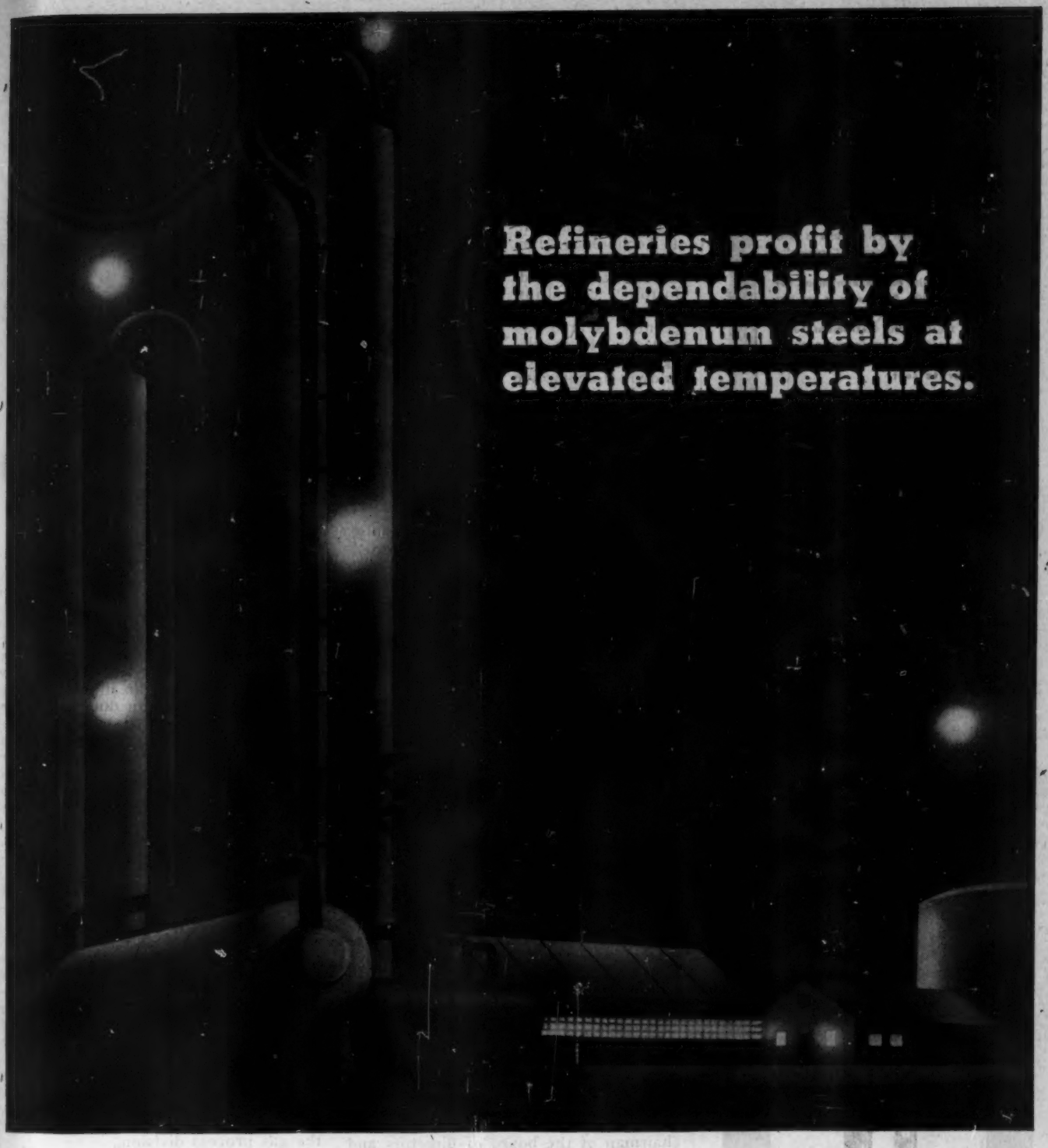
Package Machinery Company, 152 West 42nd Street, New York 18, has announced perfecting a machine for wrapping quarts of oil in paper containers at the rate of 70 per hour. The machine takes ordinary board paper in roll form and, in combination with adhesives, spirally winds into a cylinder, open at each end. One end of the cylinder is sealed before the container is filled with oil, then the other end is sealed after automatic filling. Printed labels are applied during the process. The machine is 6 feet high, 16 feet long and 4 feet wide, and requires only 2 or 3 operators.

Safety Goggle

AMERICAN OPTICAL COMPANY

American Optical Company, Southbridge, Massachusetts, has introduced a new improved Duralite safety goggle for workers who face the hazards of flying objects. Major improvement is a newly designed eye cup which is considerably larger in area and more face conforming than the previous cup, providing maximum eye protection, increased ventilation and greater comfort. Shaped separately to fit the contour of the right and left eye, the cups fit snugly against the face and protect the eyes from objects striking from the sides, top or bottom. New nasal section and enlarged facial contact roll conform to the shape of the face. Eye cups fit snugly and are designed for ample ventilation to minimize fogging.

301A Duralite Safety Goggle.



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METER

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ROTAMETERS

☆ BUSINESS NOTES ☆

Air Preheater Corporation, 60 East 42nd Street, New York 17, has announced appointment of Alexander J. Tigges as district technical advisor, with offices in New York. Tigges is a graduate of Massachussetts Institute of Technology. For 20 years he was with Jackson & Moreland, Boston consulting engineers, and more recently served as manager of consulting engineers for Baldwin Locomotive Works, Chester, Pennsylvania. He was project engineer during construction of Boston Edison's Mystic Power Station, and other important power plants, including those for a number of oil refineries in the Southwest.

A. J. Tigges

DeLaval Steam Turbine Company, Trenton, New Jersey, has appointed Charles C. Bray assistant to the manager of the worm-gear division. Before accepting this position, Bray was a metallurgist with the special steel department of Joseph T. Ryerson & Sons, Philadelphia. He is not a newcomer to the DeLaval organization, having served for 10 years as a worm-gear sales engineer out of the company's Chicago office before going with the Ryerson organization.

C. C. Bray

Houdry Process Corporation of Pennsylvania is the new corporate name of Catalytic Development Corporation, research and service subsidiary of Houdry Process Corporation. Main offices are in Lewis Tower, Philadelphia 2, and laboratories are at Marcus Hook.

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has announced election of Clarence E. Searle as president, and Hobart C. Ramsey as executive vice president. Searle succeeds Harry C. Beaver, who was elected chairman of the board of directors and management committee. Leslie C. Rickets, manager of the Harrison Works, was elected a vice president. Searle has been succeeded in his former position as vice president in charge of sales by Edwin J. Schwanhausser, who was vice president in charge of sales and manufacturing at Buffalo, New York. Ramsey formerly was vice president in charge of operations.

H. C. Ramsey

C. E. Searle

The Girdler Corporation, Louisville, Kentucky, has elected George O. Boomer its president, to succeed Walter H. Girdler, Sr., who died January 7. Boomer has been a member of the board of directors of the corporation since it was founded, and has been executive vice president since 1938. He formerly was vice president of Ewald Iron Company and president of Pittsburgh Fuel Company. He will continue as vice president and director of Tube Turns, Inc., an affiliate of The Girdler Corporation.

G. O. Boomer

Monsanto Chemical Company, St. Louis, has announced that Robinson Ord will serve as acting general manager of sales of the organic chemicals division pending return of Fred C. Renner who is convalescing from an illness and not expected to be ready for duty for two or three months. A. T. Loeffler, branch manager at New York, is assigned to St. Louis as assistant general manager of sales; A. P. Kroeger, St. Louis manager of intermediate sales, will go to New York as acting assistant branch manager, and duties of C. H. Sommer, manager of plasticizers and resins sales, will be extended to include those of acting manager of intermediate sales. F. M. Luckett, Chicago sales representative, is assigned temporarily to St. Louis to assist Sommer.

Fisher Governor Company, Marshalltown Iowa, has appointed Allan K. Cook as its sales and engineering representative in Western Kentucky and Southern Indiana, with offices at 505 South Third Street, Louisville, Kentucky. Cook is a graduate of Massachusetts Institute of Technology, and since 1934 has been connected with Henry Vogt Machine Company and The Girdler Corporation, serving the latter as chief engineer of the gas process division.

National Foam System, Inc., Philadelphia, has announced election of Hart H. Fleming as vice president to replace G. Gordon Urquhart who resigned to become president of Wilmington Chemical Corporation. Fleming has been a director of National Foam System for 15 years. He is a graduate of University of Michigan (M. E., 1917), after which he joined Standard Oil Company of New Jersey as an engineer at Bayway refinery, later moving

H. H. Fleming

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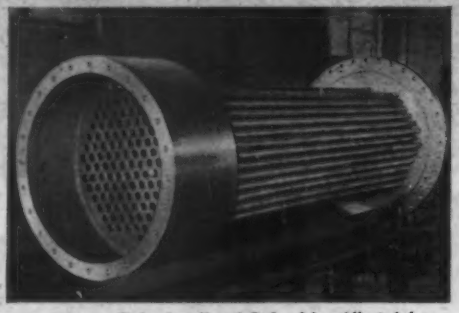

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Downingtown is a pioneer in stainless steel fabrication; the first large job in the United States was Downingtown built.

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In fabricating equipment where various grades of stainless steel are used or when a grade of stainless steel is attached to other metals, Downingtown's experience and knowledge may prove most helpful to you.

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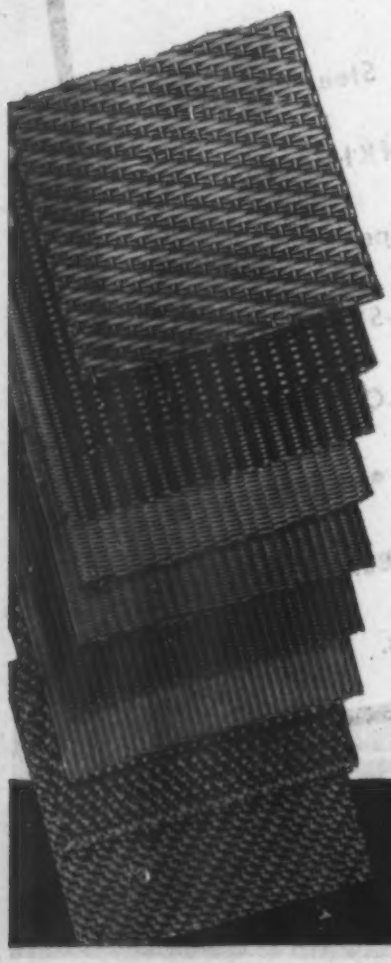

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to the New York office. In 1920 he went to Rumania for three years as chief engineer in reconstruction of Standard Oil Company's war-destroyed properties. Returning to the United States he engaged in various refinery construction and operation activities for the company, and for a period was with Standard Oil Development Company. Since 1925 he has been vice president of Johnston and Jennings, Cleveland, a connection which he will retain. Urquhart is to continue to serve National Foam System as consultant. He is a graduate of University of Pennsylvania, was one of the organizers of American Fomon Company in 1926, and has been vice president of National Foam System since 1935. As president of Wilmington Chemical Corporation he succeeds Herbert Waller, resigned, and will have headquarters at 10 East 40th Street, New York. The chemical corporation manufactures chemicals for the rubber industry in a plant at Wilmington, Delaware.

Chemical Construction Corporation has elevated Arthur E. Hecker, formerly vice president and general manager, to president, in which position he succeeds W. S. Stowell, deceased. Hecker was a captain of ordnance in World War I, and subsequently one of the principal engineers of Nitrogen Engineering Corporation whose synthetic nitrogen fixation processes were transferred to Chemical Construction Corporation in 1934. For a number of years prior to the present war, he was in charge of the European engineering offices of these companies. Blakeslee Barnes, a vice president, has assumed the additional duties of general manager, and R. E. Lapean and S. F. Spangler have been elected vice presidents.

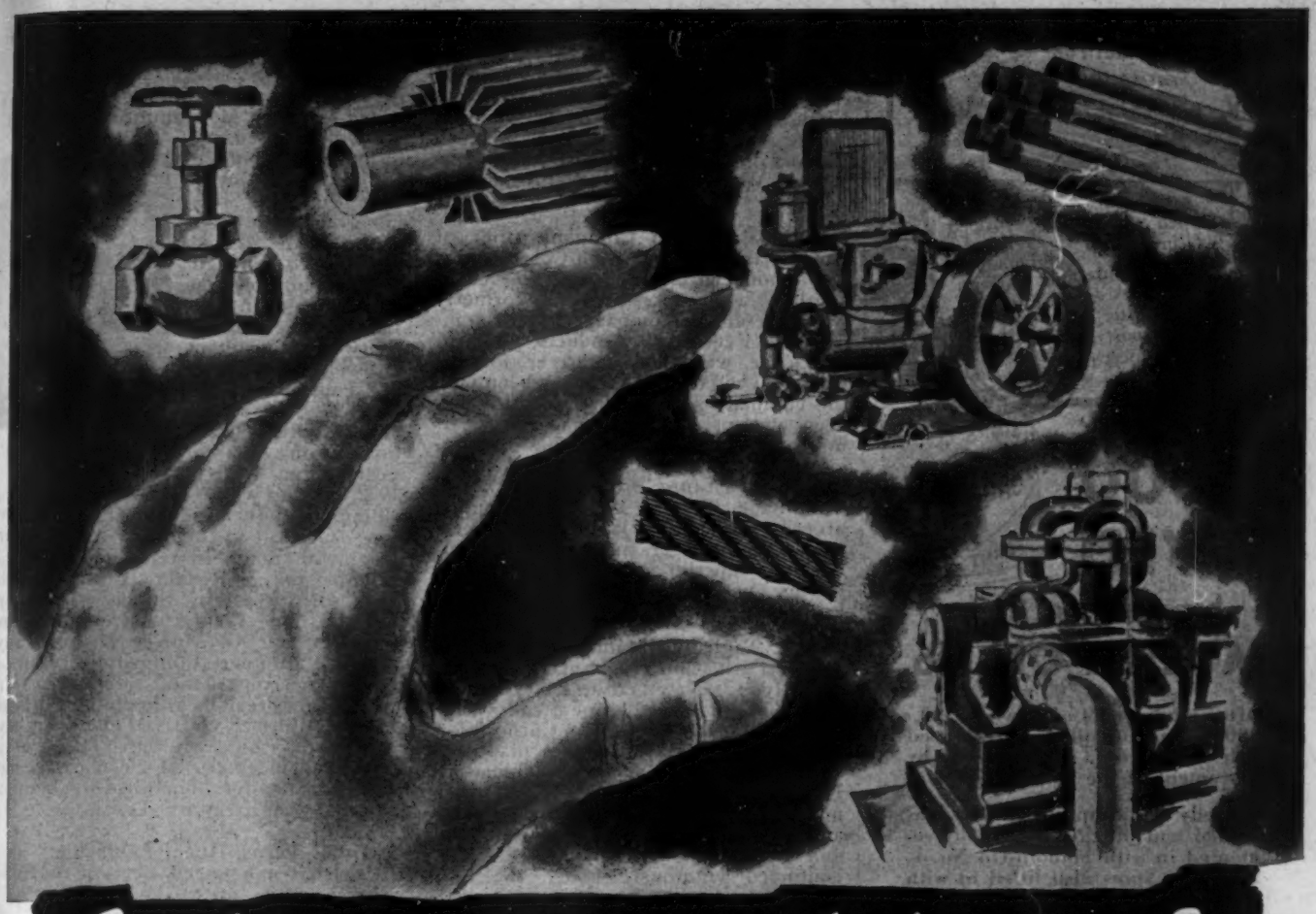
A. E. Hecker

Jones & Laughlin Steel Corporation, Pittsburgh, has announced purchase of Talon Incorporated's tube plant at Oil City, Pennsylvania. The purchaser plans to operate the plant as the Electric Weld Tube Division of Jones & Laughlin Steel Corporation, retaining the present personnel.

The Girdler Corporation, Louisville, Kentucky, has announced appointment of Sam N. Welch as sales manager of its Votator Division in the Eastern District, with offices at 150 Broadway, New York, and of L. D. Douglas, Jr., as Midwestern sales manager, with headquarters at Louisville. Welch at-

S. N. Welch

L. R. Roy, Jr.



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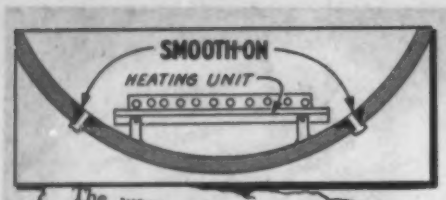
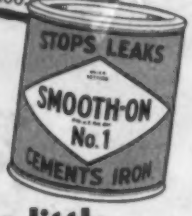


The worn sections were drilled and tapped for ⅝ in. bolts and cemented in with Smooth-On. This produced a pressure-tight plug for the hole and took only a little time and involved little or no cost, except for the labor required to drill the holes and insert the bolts. Compare this with the $2,800 o

(Clipping from *National Engineer*, Nov. 1943)



$2800 SAVED

by using a little SMOOTH-ON No. 1

After many years of service a 20,000-gallon fuel oil tank developed a leak due to a hole caused by movement of the heating element.

Remedy was simple. The hole was drilled and plugged with bolts cemented in with Smooth-On No. 1, and worn spots also filled in with additional Smooth-On; and the tank was ready for many more years of service, as reported in a recent issue of National Engineer (see reproduction above).

This Smooth-On No. 1 repair saved a heavy expenditure of $2800 for a new tank. No heat required, no serious dismantling, no delay, no material labor expense.

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tended Berea College and Purdue and Kentucky Universities. His territory includes New York, New Jersey, Pennsylvania, Delaware, Maryland and New England States. Roy attended Columbia Military Academy. His territory includes Indiana, Ohio, Illinois, Wisconsin, Minnesota, Michigan, Iowa, Nebraska and Kansas.

National Carbon Company (unit of Union Carbide and Carbon Corporation) has announced election of C. O. Kleinsmith as a vice president. He formerly was general sales manager for the company's "Eveready" products, before which he was sales manager for the Eastern United States. He has been with the company since 1919. D. B. Joy has been appointed sales manager for carbon products. Joy joined the company in 1923 after graduating from Massachusetts Institute of Technology. He was made director of the company's process engineering laboratory at Fostoria, Ohio, 10 years ago, in 1941 became assistant superintendent of the Fostoria factory, and became product manager last year.

C. J. Tagliabue Manufacturing Company, Park and Nostrand Avenues, Brooklyn 5, New York, has been acquired by and will be operated as a division of Portable Products Corporation, Pittsburgh. Assets include plants at Newburgh, New York, Philadelphia and Pittsburgh. The purchaser has announced that the progressive research and development policies in electronic and mechanical instrumentation will be continued vigorously under the local management and personnel of the purchased company.

Hooker Electrochemical Company, Niagara Falls, New York, recently received the Army-Navy award for the fifth time. The company's plant at Tacoma, Washington, received an initial award on January 9.

The Dow Chemical Company, Midland, Michigan, has appointed Ivan F. Harlow production manager of its inorganic division, where he takes over managerial duties formerly performed by Dr. E. O. Barstow who, as vice president, has taken over increased executive responsibilities. Harlow has been in direct charge of development and production of bromine and bromine compounds almost since his affiliation with the company in 1909. He is vice president and general manager of Ethyl-Dow Chemical Company, subsidiary engaged in extraction of bromine from sea water at Wilmington, North Carolina, and Freeport, Texas. Dr. Barstow joined the company three years after its incorporation in 1897. He became a director in 1931 and vice president in 1941, and also is a director of Ethyl-Dow Chemical Company, Dow Magnesium Corporation and Midland Ammonia Company.

D. B. Joy

C. O. Kleinsmith

Fischbach and Moore of Texas has added Rayburn M. Hamilton to its staff. He will be in charge of its Houston office, 736 Bankers Mortgage Building. Since his graduation from the United States Naval Academy in 1925, Hamilton has been engaged in electrical engineering activity as a consultant as well as with oil and contracting companies concerned chiefly with refining installations. For four years, from 1928 to 1932, he was with The Texas Pipe Line Company with headquarters at Houston. Other oil-company connections were with Southern Gas Company and Humble Oil & Refining Company. He was with Western Supply Company, now Gasoline Plant Construction Company, Arthur G. McKee & Company, and The Lummus Company, serving on particular construction jobs. For the three years previous to his joining Fischbach and Moore, electrical engineers and contractors, he was with The Austin Company in charge of electrical design on projects for The Dow Chemical Company at Freeport, Texas.

R. M. Hamilton

Tube Turns, Inc., Louisville, Kentucky, has announced election of R. E. Fritsch as its president, to succeed Walter H. Girdler, Sr., who died January 7. Fritsch has been vice president of the company since 1929, and will continue as a vice president and member of the board of directors of the Girdler Corporation, of which Tube Turns, Inc., is an affiliate. He is a member of the American Society for Metals and of the American Welding Society.

R. E. Fritsch

Optimus Detergents Company, Matawan, New Jersey, has announced appointment of Joseph S. Brady as technical supervisor, and A. C. Daly as technical field representative. Brady is a graduate of Rochester University and had special work in chemical engineering at Lehigh University. He formerly was with Eastman Kodak Company's technical chemicals department, and for several years was research chemist for Oakite Products, Inc. Daly is a graduate of Rutgers University, and has had experience with Wright Aeronautical Corporation and Magnus Chemical Company as consultant on metal cleaning. For several years he was technical field representative for Oakite Products, Inc.

The Lunkenheimer Company, Cincinnati, announced the following changes in executive personnel on January 1: Frank P. Rhame, a director and vice president, became general manager, succeeding Charles A. Brown, who ertired. Rhame has been with the company 25 years, and has been succeeded as assistant general manager by Homer E. Lun-

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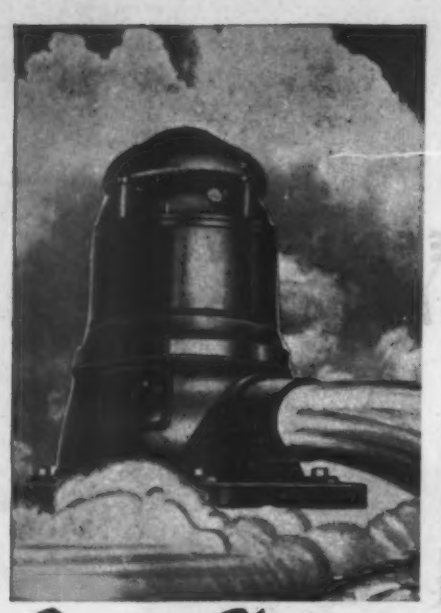

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LAYNE

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ken. C. L. Lane was made works manager to succeed George A. Seyler, vice president in charge of manufacturing, who retired. Fred H. Hehemann, assistant chief engineer, became chief engineer, in place of Jerome J. Aull, who retired after nearly 50 years of service with the company. Hehemann has been with the company since 1904.

Graver Tank & Manufacturing Company, East Chicago, Indiana, has announced appointment of Chas. W. Springer as manager of Eastern sales. He will direct the company's East Coast sales activities from its offices at 424 Madison Avenue, New York 17. Springer formerly was sales manager of the barrel division of Jones & Laughlin Steel Corporation, and for a number of years was with the sales department of Chicago Bridge & Iron Company.

C. W. Springer

North American Philips Company, 100 East 42nd Street, New York 17, has appointed Wesley L. Wilson commercial manager of its quartz crystal division. He has been purchasing agent for the company since 1942. Presently the company is devoting research and experimentation to applications in military communications equipment, and after the war plans to continue production of quartz crystals and other items used in the manufacture of electronic equipment.

The Sharples Corporation, Philadelphia, recently opened a new research laboratory, with Foster C. Nix, formerly research physicist at Bell Telephone Laboratories, as director of research.

Blackmer Pump Company, Grand Rapids, Michigan, announces that Jose Maria Fierro, who has been the company's representative in Mexico City and adjoining districts, has been appointed general representative for all of Mexico.

Peabody Engineering Corporation, 580 Fifth Avenue, New York, had a double celebration at Hotel Astor on January 29 when personnel of the plants at Stamford and South Norwalk, Connecticut, and of the New York office gathered in recognition of the company's twenty-fifth year in business, and to receive the Maritime M award.

The Kennedy Valve Manufacturing Company, Elmira, New York, has been awarded a second star for its Maritime M pennant.

United States Gauge Company, Sellersville, Pennsylvania, has announced appointment of W. S. O'Connor as its district sales manager at New York, with offices at 233 Broadway.

A. O. Smith Corporation, Milwaukee, Wisconsin, has announced election of Rae F. Bell as chairman of its board of directors, to succeed the late L. R. Smith. Bell joined the company in 1923 as a vice president, was elected a director in 1925, and has been first vice president since 1937. The company also announced election of Anthony von Wening as vice president and controller. He came to the

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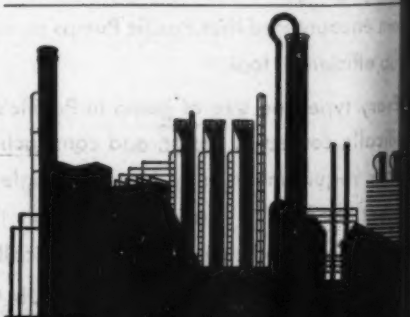

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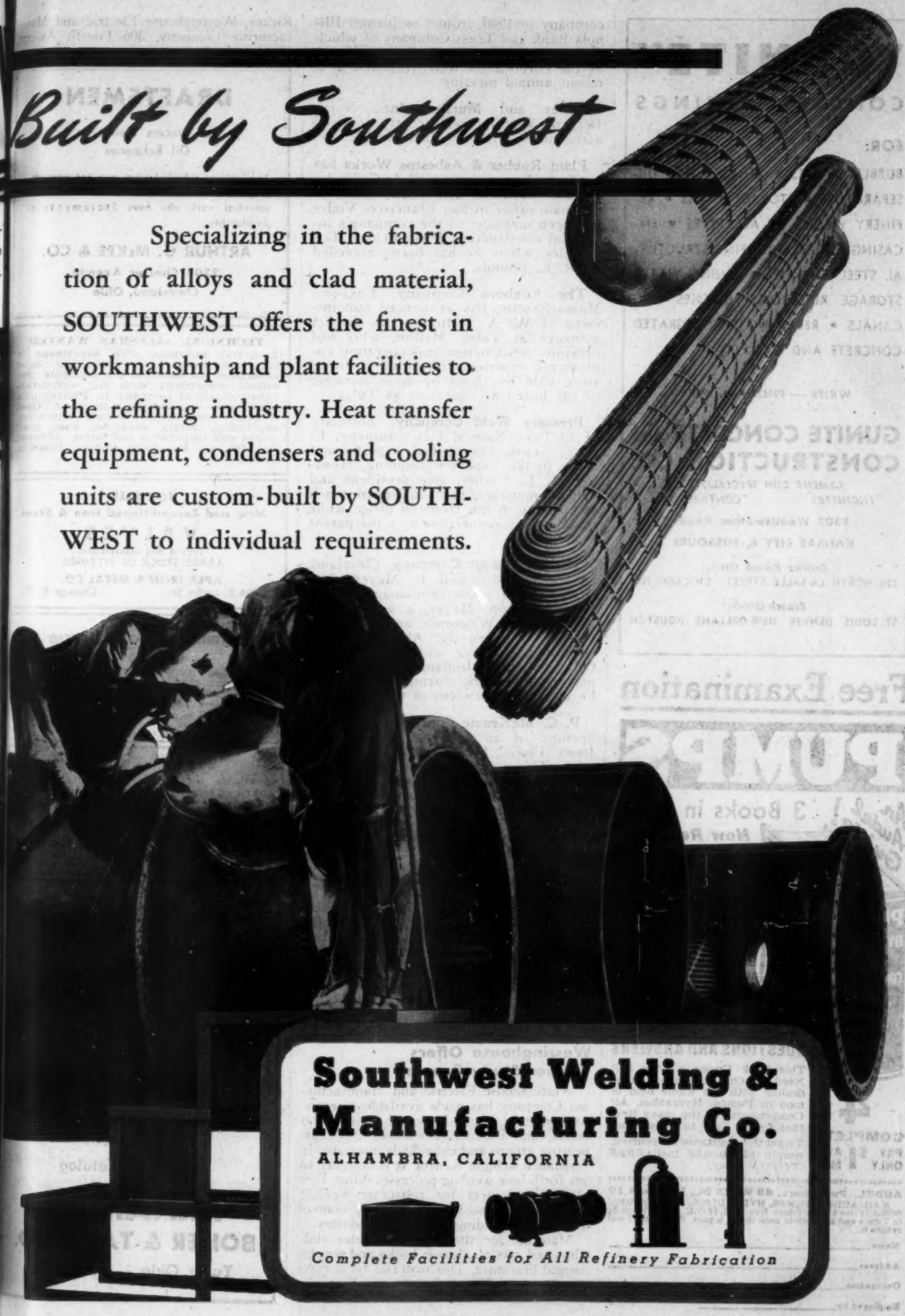

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company in 1940, from Continental Illinois Bank and Trust Company of which he was a vice president. Other officers of the corporation were reelected at a recent annual meeting.

Kieley and Mueller, Inc., North Bergen, New Jersey, recently received a second star for its Maritime "M."

Plant Rubber & Asbestos Works has announced appointment of J. C. Voiles as chief engineer, with headquarters at the main office in San Francisco. Voiles has been manager of the company's industrial construction department at Los Angeles, where he has been succeeded by R. E. Bounds.

The Foxboro Company, Foxboro, Massachusetts, has announced appointment of W. A. Melton as its district manager at Tulsa. Melton, who had previous construction and operation engineering experience in the oil business, since 1936 has been business manager of the board of education at Tulsa.

Pressure Weld Company, subsidiary of El Paso Natural Gas Company, El Paso, Texas, has opened a permanent office in the Esperson Building, Houston. A. L. Forbes, vice president and general manager, plans to spend much of his time in the Houston office while retaining his connection with the parent organization.

The Swartwout Company, Cleveland, has appointed Royal L. Meyer chief engineer and assistant manager of its steam division. Meyer, a graduate of University of Wisconsin, and recently a partner of Vern E. Alden, Chicago consulting engineer, was with Standard Oil Company (Indiana) 18 years in power-plant work, during 10 of which he was superintendent of utilities.

P. C. McKenzie Company announces opening of an office at 545 William Penn Place, Pittsburgh 19, Pennsylvania. This company is sales representative for The Griscom-Russell Company, The Fluor Corporation, and the Scovill Manufacturing Company.

The Swartwout Company, Cleveland, has advanced M. M. Ward from engineer and assistant sales manager to sales manager of the steam division.

Foster D. Snell, Inc., 305 Washington Street, Brooklyn 1, New York, recently added Dr. D. Gardiner Foulke to its staff as director of the analytical department. Dr. Foulke recently was chief chemist for Garfield Division of Houdaille-Hershey Corporation. He received his B.S. degree from Juniata College, M.S. and Ph.D. from Rutgers University.

Westinghouse Offers Welder Study Course

Westinghouse Electric and Manufacturing Company has made available a seven-part training course by sound films, lesson books, and instructors manual, for engineering groups and individuals interested in resistance welding control. It is designed to set forth how welding processes differ, how electronic control for resistance welding works, and how this method of control adapts this welding process to industry.

Material for the course includes slide films and records, lesson books and supplemental literature. This material for a class of 20 costs $50. Information about the course may be had by addressing C. R. Ricker, Westinghouse Electric and Manufacturing Company, 306 Fourth Avenue, Pittsburgh, Pennsylvania.

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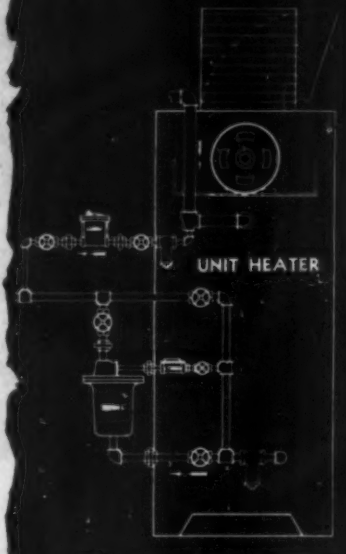
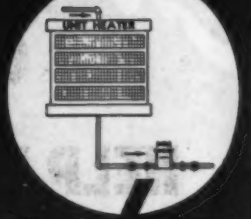


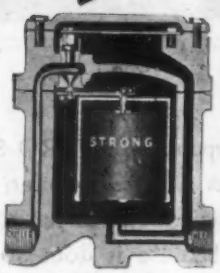
FLOOR-TYPE HEATER with Strong 70 Series trap draining inlet line, and 80 Series with Thermal Air Valve draining heater. Note strainers ahead of traps. OVERHEAD HEATER (circle) drained by Strong 70-T trap, with built-in thermal vent.



Accumulated condensate and trapped air can make unit heaters slow in starting. Uncertain drainage can seriously reduce heat output.

Leaky Traps Waste Fuel

While all Strong Inverted Bucket Traps will handle large amounts of air, the hookups shown here provide thermal air vents for practically instantaneous heating. Use of Strong anti-balanacing traps, guaranteed for a year against leakage, insures positive drainage without waste of steam.



Strong 70-T trap with built-in bi-metal air vent. For saturated steam pressures to 150 p.s.i.

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Completeness of the Strong line enables us to recommend exactly the type and size you need—open or inverted bucket, closed float, float-and-thermostatic (blast), etc.—forged, welded, cast and semi-steel construction. Send your drainage problems to Strong, Carlisle & Hammond Co., Cleveland, Ohio.

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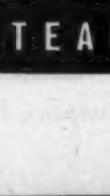
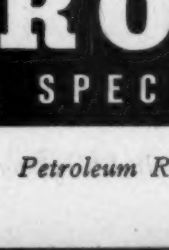
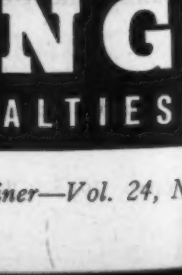


Fabricated Steel Traps



Inverted Bucket Traps



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Refrigerating Machines

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has issued Bulletin C-1100-B8 on absorption refrigerating machines.

Rotary Pumps

Blackmer Pump Company, Grand Rapids 9, Michigan has released a six-page folder, No. 306, which is a complete revision of a previous publication giving facts about rotary pumps.

Acid-Proof Brick

Belden Brick Company, Canton, Ohio, is distributing a handsome 16-page illustrated brochure which describes a new acid-proof brick floor with high resistance to abrasion, and a crushing strength of 18,500 pounds to the square inch.

Pumps

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has available a folder, W-113-B32, which gives engineering details on "Hivol" horizontal simplex direct-acting piston pumps, for handling butane, propane and other light products.

Pumps

Bump Pump Company, La Crosse, Wisconsin, is distributing a 104-page catalog describing the Bump pump principle of operation, and range of sizes in industrial and sanitary pumps. It gives operating and construction data, dimensions, horsepower charts, etc.

Springs

American Locomotive Company, 30 Church Street, New York 8, has issued Bulletin 5001, on industrial springs. In 12 pages it gives a quick digest of the most popular types of springs of the company's manufacture, together with engineering formulas and other data.

Gas-Engine Compressor

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has issued Bulletin L-685-B1, descriptive of its Type LFC angle gas-engine compressor. Featured are installations in gasoline plants and oil refineries. Full construction and engineering details are included.

Corrosion

Worthington Pump and Machinery Corporation, Harrison, New Jersey, is distributing the second number of a leaflet, 'Worthite News," published in the interest of overcoming corrosion problems. The current number features pumps for handling plating solutions.

Piping, Vessels, Heat Exchangers

American Locomotive Company, 30 Church Street, New York 8, has issued Bulletin 1034 on "Alco Triple Service," which gives details of the company's services in prefabricated piping, pressure vessels and fabricated plate work, and heat-exchange equipment. Engineering tables and design data are included.

Carbon and Graphite Products

National Carbon Company, 30 East 42nd Street, New York 17, is distributing Catalog Section M-8000-A, "'National' and 'Karbate' Carbon and Graphite Products." In 20 pages it describes and illustrates a wide variety of carbon, graphite and "Karbate" products for use in chemical and other industries. Charts and tables give data on physical and chemical properties, together with application and operational information.

Silver-Soldering Flux

Superior Flux Company, 913 Public Square Building, Cleveland, Ohio, has issued a four-page bulletin which describes its patented flux for silver soldering and gives detailed instructions for its use.

Industrial Electronics

General Electric Company, Schenectady, New York, has available its publication GEA-4309, a reprint of a series of articles by G. M. Chute, published in *Steel*. It is a handy reference on industrial electronics.

X-Ray Diffraction

North American Philips Company, 100 East 42nd Street, New York 17, has issued a four-page leaflet "X-Ray Diffraction—An Industrial Tool," which explains the technique employed in "Norelco" film-type X-ray equipment

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Stacey Brothers are experienced producers of storage tanks for oil, gasoline, natural and manufactured gases. Also processing equipment such as Condensers, Scrubbers, Fractionating Towers, Pressure Vessels, etc.

All shapes and sizes of structures—made of steel or steel alloys in welded or riveted constructions; and furnished as shop or field-erected units. Send us blueprints and specifications if available—or give detailed description of requirements.

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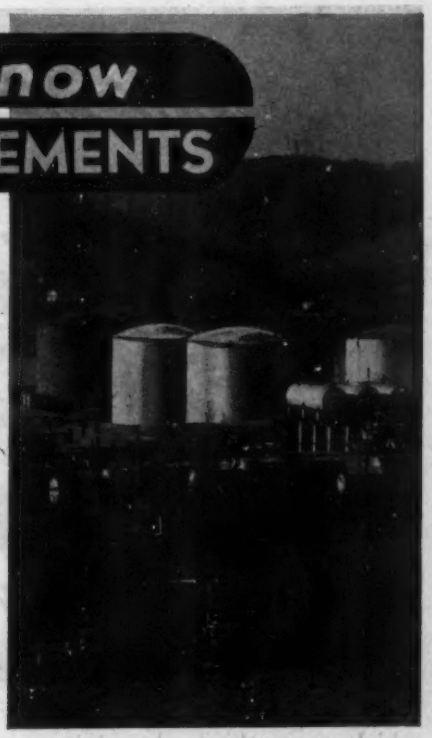
Stacey Brothers



Partial view of several Stacey Brothers gasoline storage tanks installed along the Ohio river.

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This BIG Lonergan Safety Valve... discharges 178,800 lbs. Steam per hr. at 300 p.s.i.

This Little Fellow... discharges 605 lbs. per hr. at the *same pressure*

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BOTH are efficient and dependable—represent fine engineering and construction—and illustrate the wide range of selection in Lonergan Safety Valves.

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SINCE 1872 — *Makers of Pressure-Safety Appliances for the Power, Mechanical and Process Industries*

For strength and simplicity, only two parts are used — bearing bars which carry the load and have curved slots punched ABOVE THE NEUTRAL AXIS, and cross bars, of the same cross sectional area as the slot itself, pressed into these slots to distribute the load. No rivets, bolts or welds are required, thus eliminating the possibility of loose joints. Tri-Lok flooring comes in rectangular, diagonal and U shapes with Safety Steps — ask for Bulletin 1140 — DRAVO CORPORATION, NATIONAL DEPARTMENT, 300 Penn Avenue, Pittsburgh (22), Pa. (Distributor for THE TRI-LOC COMPANY)

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for identification of materials. Simple sketches representing typical diffraction films are exhibited in order to show how comparisons are made.

Time-Schedule Controller

Taylor Instrument Companies, Rochester 1, New York, is distributing Bulletin 98165, on the Taylor Fulscope Time-Schedule Controller. The bulletin is liberally illustrated with photographs of applications, and cut-away views of the instrument.

Flow Indicator

Fischer & Porter Company, 919 County Line Road, Hatboro, Pennsylvania, has published its Catalog 92-C on "The Rotasight Flow Rate Indicator and Flow Rate Alarm." This instrument operates on the rotameter area-type principle with a float which rises in proportion to the flow. The catalog gives construction details and applications, engineering dimensions, and prices.

Pipe Stress Calculation

The M. W. Kellogg Company, 225 Broadway, New York 7, has released data, in its publication, "The Kellogram" issue No. 5, on apparatus developed by the company's engineers to solve pipe-stress determination problems which are beyond the practical scope of mathematical computation.

Air Compressors

Ingersoll-Rand Company, 11 Broadway, New York 4, is distributing a 24-page booklet, No. 1011, "A Little Air Power Will Do Many a Big Job." Mainly photographic, it shows how to put familiar air-operated equipment to work in many new ways. It also catalogs the company's lines of air compressors in all sizes.

Steel Tubes

Formed Steel Tube Institute, Cleveland, Ohio, is distributing a handsome illustrated booklet on "Better Products With Electric Welded Tubing." Written for product designers, it contains specifications for various tubing applications and offers a very complete handbook to engineers who may be interested.

Strainers

J. A. Zurn Manufacturing Company, Erie, Pennsylvania, has issued a new catalog, No. 45, on fluid-handling equipment for industrial installations. It features a complete line of suction and pressure line strainers. Other products described are interceptors for grease, wax, etc., for maintaining continual flow through pipes.

Condenser-Tube Inlets

Condenser Service & Engineering Company, Hoboken, New Jersey, is distributing a new bulletin on "Flowrites," short belled-end metal inserts which protect condenser-tube inlets against corrosion. Data is presented to show these inlets reduce fluid friction, which lowers power required for pumping, and by causing smooth flow prevents release of corrosive gases.

V-Belt Drives

Allis-Chalmers Manufacturing Company, Milwaukee 1, Wisconsin, has issued its Catalog B6051E on V-belt drives. It presents required information for making drive selections in charts, tables and drawings.